Scythe

Proceedings and Bulletin of the International Data Farming Community

Issue 2 - Workshop 14

Proceedings and Bulletin of the International Data Farming Community

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Scythe

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It is appropriate that the publication supporting the International Data Farming Workshop is named after a farming implement. In farming, a scythe is used to clear and harvest. We hope that the "Scythe" will perform a similar role for our *data* farming community by being a tool to help prepare for our data farming efforts and harvest the results. The Scythe is provided to all attendees of the Workshops. Electronic copies may be obtained from harvest.nps.edu Please contact the editors for additional paper copies.

Please let us know what you think of this second prototype issue. Articles, ideas for articles and material, and any commentary are always appreciated.

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International Data Farming Community Overview

The International Data Farming Community is a consortium of researchers interested in the study of *Data Farming*, its methodologies, applications, tools, and evolution.

The primary venue for the Community is the biannual International Data Farming Workshops, where researchers participate in team-oriented model development, experimental design, and analysis using high performance computing resources... that is, Data Farming.

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IDFW 14:
The Seeds of Learning

by Gary Horne
Naval Postgraduate School

International Data Farming Workshop 14 (IDFW 14) took place during the 6 days from March 25th through the 30th, 2007 in Monterey California. Seventy-five participants from seven countries worked in thirteen different teams exploring questions using Data Farming methods. The theme was "The Seeds of Learning," and the goal was that many seeds would be planted and would continue to be developed in the future. The theme also reflects the name of our growing Center at the Naval Postgraduate School in Montery, the SEED Center for Data Farming.

SEED stands for Simulation Experiments and Efficient Designs and in 28 words the mission of the Center is: To advance the collaborative development and use of simulation experiments and efficient designs to provide decision makers with timely insights on complex systems and operations using Data Farming. As the executive director of the Center it is my pleasure to work with many from around the world to develop the methods of Data Farming and apply them to important questions of our day. The SEED Center for Data Farming was proud to sponsor this workshop and on behalf of the Center I would like to say thank you to the team leaders and participants in IDFW 14.

Next I will briefly mention the work of the 13 teams and invite you to examine the details later in this issue of The Scythe. This issue also contains a summary of the plenary sessions and concludes with an article on PAX, an agent-based model developed in Germany designed for peace support operations.

Team 1 used the simulation system "PAX" (Latin for peace) to gain insight into specific aspects of peace support operations and crowd & riot control Team 2's primary goal was to test the ability of the agent-based simulation Pythagoras to rapidly prototype a chemical environment and its affects on mobile forces. Team 3 used ITSimBw and worked on the question: How do communication aspects affect operations in urban terrain? Team 4 expanded on previous efforts on information sharing and used NetLogo to more explicitly represent cognitive and collaborative processes. Team 5 explored ways to face the challenge of examining the multitude of possible interactions and outcomes in systems-of-systems constructs and the implications for test planning. Team 6 also worked in the area of Joint Test and Evaluation of systems of systems, but from the wider lens of Capability Test Methodology. Team 7 applied automated red teaming in a maritime scenario. Team 8 continued their work in the area of Combat Identification. Team 9 was non-defense related, exploring healthcare applications of data farming. Team 10 compared ground-based fire support capabilities of Marine units using MANA. Team 11 used IWARS in examining a variety of issues related to the US Army Future Force Warrior program. Team 12 focused on design of experiment issues in applying the Joint Dynamic Allocation of Fires and Sensors simulation. And finally, team 13 made progress in modeling technical aspects of net-centric operations in a convoy protection scenario.

Along with the work of the 13 teams, we were fortunate at IDFW 14 to have the benefit of many plenary sessions and speakers and these presentations can be found on the enclosed CD. I would like to thank all of them and, in particular, our keynote speakers, VADM Moises Gomez Cabrera from Mexico, Col Joe Smith, Director of the US Marine Corps Analysis Directorate in Quantico, and LTC Jeff Schamburg, Director of the US Army Analysis Center in Monterey.

Also, I would like to acknowledge John Wasser for his efforts in coordinating the workshop as well as the many efforts of the co-directors of the SEED Center for Data Farming, Professors Tom Lucas and Susan Sanchez. And one more thank you for a job well done goes to Ted Meyer for collecting and publishing the work in this issue of The Scythe. And please note that Ted and I can be contacted at datafarming@verizon.net with questions or comments.

Now looking ahead, our Data Farming community is fortunate to have an exciting venue for our next workshop. International Data Farming Workshop 15 will be held in Singapore. It will start with the opening dinner on Sunday 11 November, 2007 and continue through the week with the closing session on Friday 16 November. I hope to see you there!

And just one final note for those of you who might have missed the last day of IDFW 14. What was in the black bag? It contained seeds, of course, and seeds in many stages: some ready to plant, some still budding, and even a growing cypress tree. Many seeds... like the many ideas and applications you are welcome to read about on the following pages. Enjoy!

Gary Horne

Team 1: Crowd and Riot Control Analysis with PAX

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INTRODUCTION

The Crowd & Riot Control (CRC) Analysis Team at International Data Farming Workshop 14 used the simulation system "PAX" (Latin for peace) to gain insight into specific aspects of peace support operations (PSO) and crowd & riot control.

The agent-based model PAX concentrates on modeling peace support operations on a detailed level. PAX was developed by the EADS System Design Center, initiated and funded by the German Bundeswehr Army Training, Doctrine and Army Development Command and assisted by the Operations Research and CD&E Branches of the Bundeswehr Center for Transformation. Both military expertise and empirical findings from psychological research on aggression were used in the construction of PAX.

PAX is able to show dependencies between the soldiers' behavior – including measures of de-escalation – and the escalation of violence, which may occur between soldiers and civilians as well as between different civilian groups. To analyze this in detail, PAX allows the investigation of a broad variety of measures of effectiveness (MOEs), e.g. the level of escalation, the number of civilians and/or soldiers who get injured and/or killed or the average fear within specific civilian groups etc.

The main goals of team 1 at IDFW14 were to:

1. Test the new PAX version and review and face validate the upgrades made to the PAX model and tools between IDFW 13 and IDFW 14, especially the implementation of extended possibilities for the setup of scenarios (such as more flexible rule sets for the soldiers and the ability to give detailed cognitive motives to the civilians).
2. Develop and test a potentially violent CRC scenario with different civilian groups. Develop and test alternative vignettes using different approaches with respect to the tactics, techniques and procedures (TTP) of the security forces by comparing different user-defined rule sets to the predefined ones.
3. Conduct experiments with different designs (both NOLH and gridded).
4. Gain insight into other models (participation in plenary sessions).
5. Provide information about the simulation model PAX (plenary session briefing on the new version PAX 3.0).

Scenario

The base scenario used during International Data Farming Workshop 14 (IDFW14) addressed a checkpoint operation in a post war country. In this scenario, different – potentially opposing – civilian groups are modeled and the effects of various TTPs of the military forces are simulated and analyzed.

The situation in the checkpoint area is expected to be initially calm, but have the potential for escalation due to opposing groups in the area and the effects of the recent war on the civilian population.

The base case scenario is shown in Figure 1. An urban area is divided into a western and an eastern part by barriers with a directed checkpoint installed and controlled by the PSO force.

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Figure 1: Scenario

In the PAX scenario (see Figure 2), there are two ethnic groups, simply referred to as northern and southern. While the southern group is supposed to be generally more benefited, the northern group suffers more unemployment and feels disadvantaged. The "Northern workers" – identified by a round shape – and the "Southern workers" identified by a hexagon shape both want to cross the checkpoint from west to east, in an attempt to go to work.

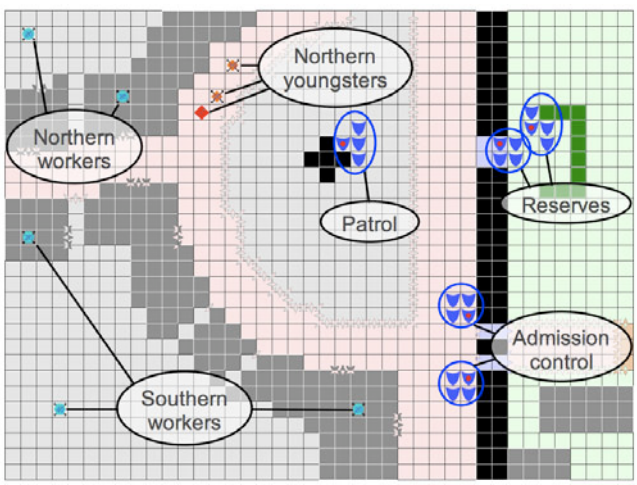


Figure 2: PAX scenario

Besides these two groups, there is a group of "Northern youngsters", ethnically belonging to the northern group, who are rather frustratedly "hanging around" in the area and whose intention is not to cross the checkpoint but rather to disturb the other group and generally to interfere with the military operation.

The military force in the scenario consists of 5 squads: Two reserve squads, one patrol squad and two admission control squads at the checkpoint with the mission of checking for unauthorized persons (in this scenario all civilians of group "Northern youngsters") and weapons carried by checkpoint crossers (which are confiscated if found).

ANALYSIS

The main objective of the CRC Analysis group was to evaluate the possibilities of the new PAX version 3.0. Thus, the new features such as user-definable soldier rule sets as well as user-definable cognitive motives of the civilians were extensively tested and analyzed in order to see how well these features provide flexibility in the scenario setup, allowing for the creation of more realistic and adequate scenarios.

The main focus of the analysis was to examine how the different soldier rule sets, e.g. Rules of Engagement (RoEs), affect the situation in terms of the

- overall escalation of the situation,
- number of casualties on soldiers' side,
- number of casualties on civilians' side and the
- number of workers passing the checkpoint.

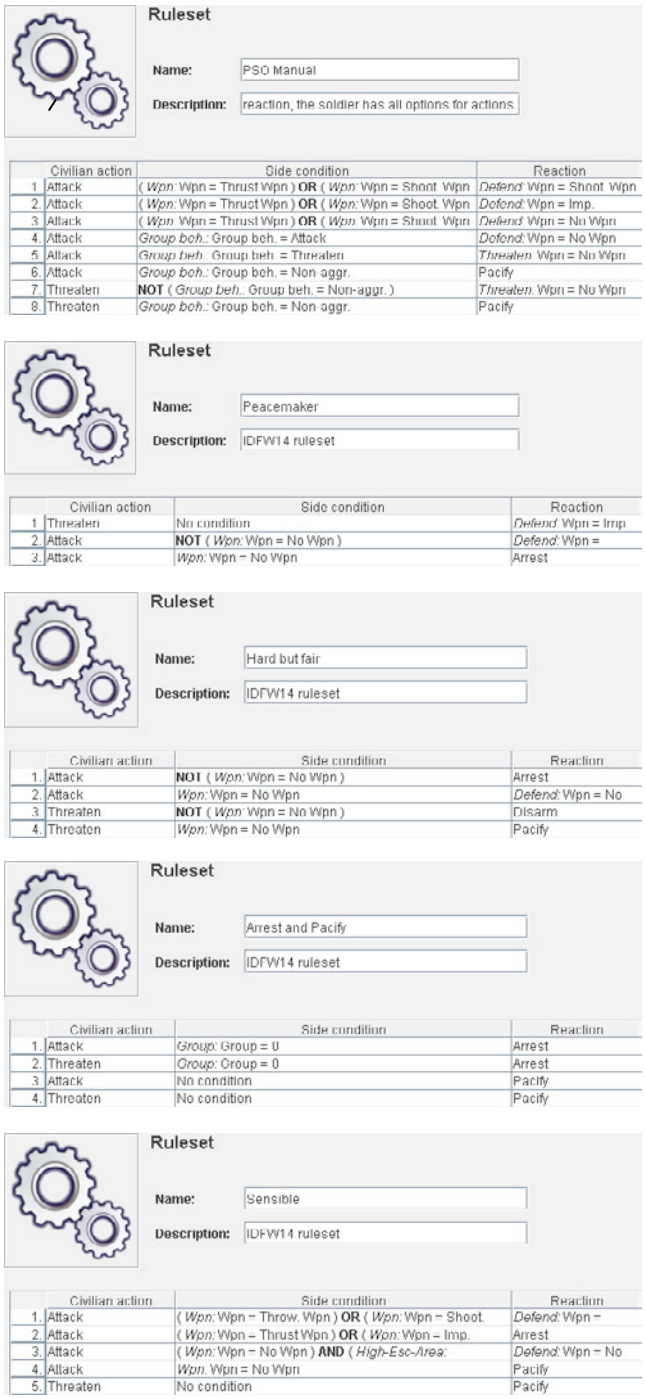
Determining important model factors

During the Data Farming (DF) process, PAX parameters of main interest and presumable importance with respect to the model and the scenario under examination were identified. Thus a number of parameters were analyzed in a simulation experiment using the Nearly Orthogonal Latin Hypercube (NOLH) design provided by the Naval Postgraduate School (NPS) Monterey, CA, USA.

The NOLH design used contained 13 parameters which are shown in Table 1. Each design point was calculated using a MultiRun of the simulation model PAX with 30 replications with different random seeds.

Parameter farmed over	Min	Max
Reserves: Threshold for intervention	0	200
All soldiers: Threshold calling for reinforcement	0	100
Northern youngsters: Dog factor	0.75	1.33
Northern youngsters: norms for anti-aggression	0	40
Northern youngsters: Readiness for aggression	50	90
Northern youngsters: personality constant anger	0	100
Northern youngsters: Personality constant fear	50	100
Northern youngsters: Willingness for cooperation	0	50
Northern workers: Norms for anti-aggression	0	40
Southern workers: Norms for anti-aggression	0	40
All workers: Dog factor	0.75	1.33
All workers: Personality constant anger	0	100
All workers: Personality constant fear	0	100

Table 1: Parameters varied in NOLH design study



Ruleset

Name: PSO Manual

Description: reaction, the soldier has all options for actions.

	Civilian action	Side condition	Reaction
1.	Attack	(*Wpn:* Wpn = Thrust Wpn) **OR** (*Wpn:* Wpn = Shoot. Wpn	*Defend:* Wpn = Shoot. Wpn
2.	Attack	(*Wpn:* Wpn = Thrust Wpn) **OR** (*Wpn:* Wpn = Shoot. Wpn	*Defend:* Wpn = Imp.
3.	Attack	(*Wpn:* Wpn = Thrust Wpn) **OR** (*Wpn:* Wpn = Shoot. Wpn	*Defend:* Wpn = No Wpn
4.	Attack	*Group beh.:* Group beh. = Attack	*Defend:* Wpn = No Wpn
5.	Attack	*Group beh.:* Group beh. = Threaten	*Threaten:* Wpn = No Wpn
6.	Attack	*Group beh.:* Group beh. = Non-aggr.	Pacify
7.	Threaten	**NOT** (*Group beh.:* Group beh. = Non-aggr.)	*Threaten:* Wpn = No Wpn
8.	Threaten	*Group beh.:* Group beh. = Non-aggr.	Pacify

Ruleset

Name: Peacemaker

Description: IDFW14 ruleset

	Civilian action	Side condition	Reaction
1.	Threaten	No condition	*Defend:* Wpn = Imp.
2.	Attack	**NOT** (*Wpn:* Wpn = No Wpn)	*Defend:* Wpn =
3.	Attack	*Wpn:* Wpn = No Wpn	Arrest

Ruleset

Name: Hard but fair

Description: IDFW14 ruleset

	Civilian action	Side condition	Reaction
1.	Attack	**NOT** (*Wpn:* Wpn = No Wpn)	Arrest
2.	Attack	*Wpn:* Wpn = No Wpn	*Defend:* Wpn = No
3.	Threaten	**NOT** (*Wpn:* Wpn = No Wpn)	Disarm
4.	Threaten	*Wpn:* Wpn = No Wpn	Pacify

Ruleset

Name: Arrest and Pacify

Description: IDFW14 ruleset

	Civilian action	Side condition	Reaction
1.	Attack	*Group:* Group = 0	Arrest
2.	Threaten	*Group:* Group = 0	Arrest
3.	Attack	No condition	Pacify
4.	Threaten	No condition	Pacify

Ruleset

Name: Sensible

Description: IDFW14 ruleset

	Civilian action	Side condition	Reaction
1.	Attack	(*Wpn:* Wpn = Throw. Wpn) **OR** (*Wpn:* Wpn = Shoot.	*Defend:* Wpn =
2.	Attack	(*Wpn:* Wpn = Thrust Wpn) **OR** (*Wpn:* Wpn = Imp.	Arrest
3.	Attack	(*Wpn:* Wpn = No Wpn) **AND** (*High-Esc-Area:*	*Defend:* Wpn = No
4.	Attack	*Wpn:* Wpn = No Wpn	Pacify
5.	Threaten	No condition	Pacify

Figure 3: Rule sets examined

When analyzing the data with the help of commercial off the shelf (COTS) statistical software, it became clear that the parameter that had the most significant impact on numerous MOEs was the parameter responsible for the change of the anger levels of the Northern Youngsters group (PAX parameter "PC_Anger"). The effect of this parameter was most clearly seen in the aggregated escalation of civilians during the simulation.

Examining different Rules of Engagement

Therefore, it was decided to set up a gridded design experiment varying this "PC_Anger" parameter[1] together with a controllable parameter, the "threshold for intervention" of the reserves.

In addition, corresponding with the team goal of assessing the effect of different RoEs, five vignettes were set up each with a different set of RoEs for the soldiers. Each member of the group had the chance to set up a rule set for the Rules of Engagement (RoEs) of the security forces. Therefore the new rule set editor of the new PAX version 3.0 was successfully tested as a side effect of this experiment.

The four rule sets which were each built by one member of the group, respectively, could thus be compared to the "PSO Manual" rule set which was built into previous versions of PAX and is now still shipped with PAX as a predefined rule set. The "PSO Manual" rule set represents a moderate reaction to civilian actions trying to create a balance between an immediate sharp reaction and a complete laissez-faire attitude. Figure 3 shows the rules of the "PSO Manual" rule set and of the different rule sets created by the team members.

It can be seen, for example, that compared to the "PSO Manual" rule set, the "Peacemaker" appears simpler, using a smaller number of rules and selecting more drastic reactions in order to keep the situation under control right from the start, prevent escalation and protect the soldiers.

All in all the gridded study consisted of 3600 single PAX runs performed on a 128 node cluster in Friedrichshafen / Germany. This set of runs had the following characteristics:

- Parameters varied:
  - Northern Youngsters: PC_Anger
    - Min 0, max 100, step size 20
  - Reserves: Threshold for intervention
    - Min 0, max 200, step size 40
  - All soldiers: Ruleset
    - "PSO Manual"

1 Note that this parameter cannot usually be influenced by military forces in a real world situation since it represents personality characteristics of the individual civilians.

- "Peacemaker"
- "Hard but fair"
- "Arrest & Pacify"
- "Sensible"

- Number of replications: 20

Comparison of the rule sets

The analysis of the result landscapes of the gridded experiment showed that the "standard" rule set "PSO Manual" that had been in use so far still proved to be very robust with regard to not only a single MoE like "Overall Aggregated Escalation" but also considering others like "Number of Civilians that passed the checkpoint" or "Number of Casualties". While other rule sets proved to be more effective on some MOEs such as reducing the important probability of soldiers being killed, they had major disadvantages with respect to other MOEs such as the number of civilians being killed or the overall escalation.

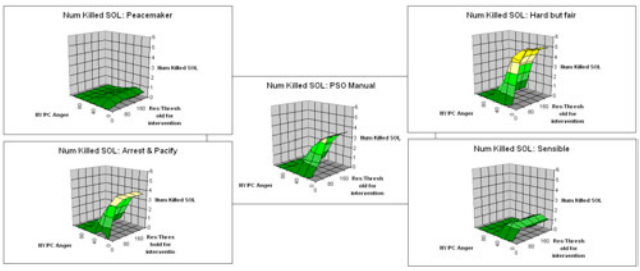


Figure 4: Performance of Rule Sets: Killed Soldiers

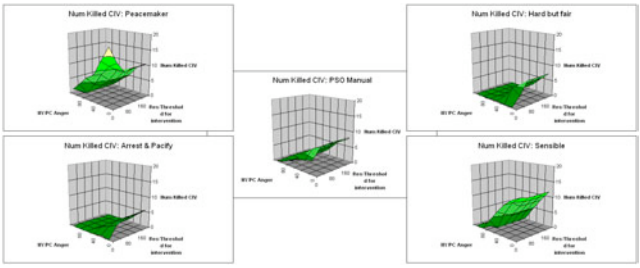


Figure 5: Performance of Rule Sets: Killed Civilians

The results were examined in more detail looking at the course of action (CoA) of relevant single PAX runs which provided insights into specific reasons for the performance of the different RoEs, such as showing that an early show of force can have advantages in scaring potential aggressors away or that a restricted area of responsibility of the reserves can lead to severe escalation between the civilian groups, to name only two examples.

Comparing different cognitive motives

Another new tool of the PAX version 3.0 is the Motive Editor that allows the user to define *cognitive* motives a civilian is to follow in addition to the existing motives like anger or fear built into PAX. Examples for such a cognitive motive are *need* or *voting motivation*, motives which used to be defined as regular motives. In the new version of PAX these motives are defined as cognitive motives, giving users the ability to flexibly modify them to fit their needs. A cognitive motive can be seen as a "plan" the civilian wants to follow and allows the user to program scripted behavior for the civilians up to a certain extent.

In the mid-term the ability to change TTPs not only for the soldiers but also for the civilians paves the way for some sort of war-gaming applications with PAX where BLUE TTPs can be improved to match RED TTPs and vice versa. A first attempt at testing the new flexibility provided by these cognitive motives was made by team 1 at IDFW14 by setting up a cognitive motive for a subgroup of the group of northern youngsters so they would assault the southern workers. Figure 6 shows the Motive Editor with the mentioned cognitive motive "Assault" loaded.

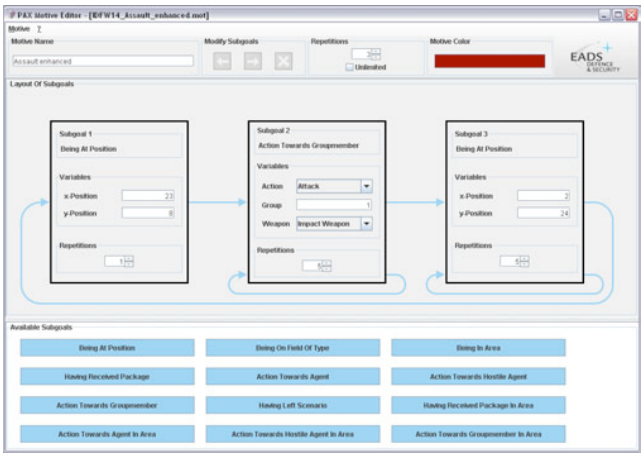


Figure 6: PAX Motive Editor

This example of a cognitive motive consists of three subgoals:

1. Approach the southern part of the area near the checkpoint where the southern workers are expected.

2. Perform five attacks against southern workers.
3. Retreat to the northwestern part of the area[2].

Each civilian assigned this motive will try to sequentially achieve these subgoals for three times (see global number of repetitions) as long as no other motive (such as a high anger or high fear) has a higher motivational power.

The motivation behind this cognitive motive was to make the northern youngsters "smarter" in directly addressing the southern workers instead of randomly engaging in fights with the patrol on the square. This expected behavior was indeed observed when looking at single simulation runs using the "Assault" cognitive motive. Figure 7 shows the situation shortly after the beginning of the simulation – while the majority of the northern youngsters have already started to fight the patrol and reserves on the square and are even starting to back off, a small group of five has made their way down to the southern part where they concertedly attack southern workers.

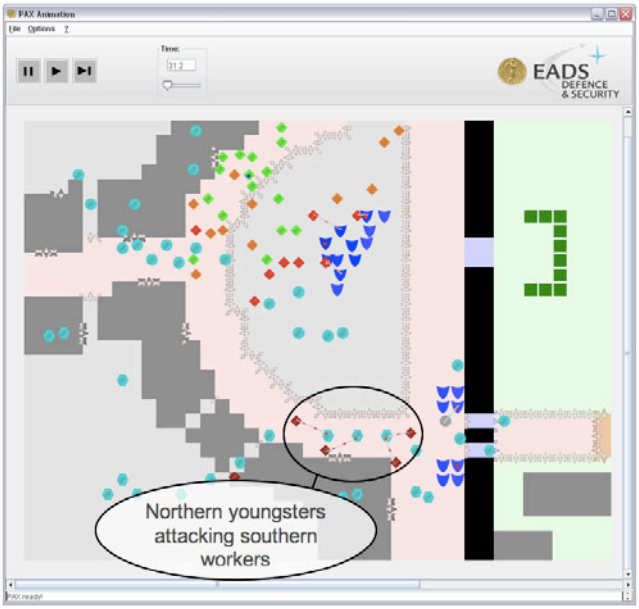


Figure 7: Effects of the cognitive motive "Assault"

Due to the limited amount of time available the team could only scratch the surface of what can be modeled using the Motive Editor. Other cognitive motives were briefly examined including one in which a subgroup of the northern youngsters picks a fight amongst themselves, which was not possible before the introduction of the Motive Editor (see Figure 8). This shows that the new PAX version provides many possibilities yet unthought of.

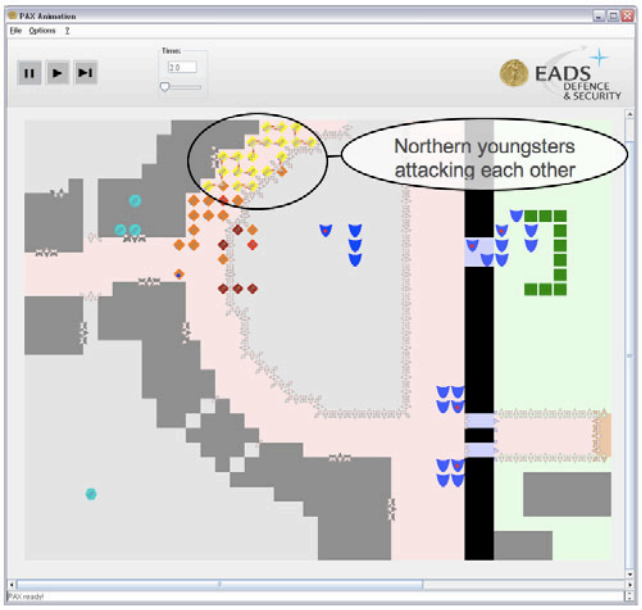


Figure 8: Cognitive motive "Self-attack"

SUMMARY / OUTLOOK

The "Toolbox" version 3.0 of PAX proved to be a big enhancement, even though further calibration is necessary. The rule set editor allows to set up RoEs of soldier agents in a flexible user-definable way. The editor for cognitive motives of the civilians allows users to define how specific (groups of) civilians try to achieve a set of sub goals. These new possibilities make it significantly easier to model a real-world scenario or examine different TTPs on both the soldiers' and the civilians' side and seem to even provide a lot of potential for future applications in fields like border security or disaster relief operations.

Having an international participant with a psychological background tremendously helped to broaden the view and to get new perspectives and insights for the further development of PAX as well as other possible fields of activity.

2 This subgoal is set to be achieved five times in order to make the civilian stay at the specified position for five time units. A subgoal "Wait" will make this technical artifice obsolete in future versions of PAX.

Team 2: Situation Awareness of an Infantry Unit in a Chemical Environment

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INTRODUCTION

The team's primary research goal was to test an agent-based simulation's capability to rapidly prototype a chemical environment and its affects on mobile forces. Specifically, the overall research effort studies levels of chemical situation awareness (SA) and their impact on combat effectiveness of a Future Force Warrior (FFW) platoon using the agent-based simulation Pythagoras.

Pythagoras is a low-resolution simulation that enables rapid model development using agents, such as individual soldiers or chemical clouds, with assigned simple behaviors. These simple behaviors tend to produce complex results when coupled with varying experimental factors and multiple agent interactions. To efficiently explore the effects of complex results across numerous factors requires advanced experimental designs, flexible modeling tools, high-performance computing, and advanced data analysis capabilities.

This research highlights findings regarding combat effectiveness at various levels of chemical SA and recommends whether Pythagoras is a viable tool to model chemical environments. Specifically, the following points will be used as guidelines of the research:

- Produce a reasonable non-persistent agent scenario, including the modeling of SA in Pythagoras.
- Consider a variety of diverse measures of performance and effectiveness.

Description of Scenario

The initial scenario stems from prior research completed by MAJ Jon Alt, a graduate of the Naval Postgraduate School. It simulates a FFW capable platoon conducting a movement to contact operation in an urban environment. To adapt his simulation for our use we needed to add additional sensors and agents to model the non-persistent chemical environment and its effects on the platoon.

The first modeling addition was the chemical agent. Two ways of modeling the agent were discussed. First, we would be able to model the chemical effects through the use of constant indirect fire and damage functions. Second, we could model the effects using actual model agents who would fire at the modeled human agents in the scenario. After discussion of the benefits of both modeling options, we decided to use the latter method.

Since there are different levels of dosage of chemical agents, we modeled two types of chemical entities. The lethal dose of the chemical agent was represented by agents who carried a weapon that "shot" chemicals at the human agents. The non-lethal dose was represented by agents who also carried a weapon to "shoot" chemicals at the human agents, but the non-lethals' weapon had no lethality (or effectiveness) so as not to actually kill a human agent.

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In order to trigger a reaction in the human agents from being shot by the chemical agents, we utilized Pythagoras' attributes. Three generic attributes are given to each model entity. As the human entities get shot, they receive damage in the form of an increase in their attributes. Once these attributes get to a threshold level, a state change is triggered. This, in effect, modeled a self-detection of the chemical. Once a detection occurred, the blue forces were directed to put on their chemical protective mask, move to a rally point, and, after a period of time to report the incident, to continue their mission to secure a certain piece of terrain.

Another addition to the initial simulation was the addition of mechanical chemical detectors. The detectors were modeled after the Joint Chemical Agent Detector (JCAD) by decreasing the threshold level at which they would make a self-detection. In other words, the JCAD is simply modeled by allowing the human agents with this device to make near-instantaneous self-detections instead of adding the JCAD as a separate sensor.

Modeling SA

In order to model situation awareness, we decided to script four plausible scenarios. The four scenarios branch from the combination of two levels of SA from their initial intelligence prior to the start of the mission and two possible distributions of the JCAD within the platoon. Therefore the four separate scenarios were as follows:

- No prior intelligence and the platoon leadership and unmanned ground vehicles carrying the JCAD
- No prior intelligence and only the platoon leadership carrying the JCAD
- Prior intelligence and the platoon leadership and unmanned ground vehicles carrying the JCAD
- Prior intelligence and only the platoon leadership carrying the JCAD

Figure 1 is a screen shot of the first scenario listed above. The green agents in the picture are the representation of the chemical IED after the explosion. It also shows the blue agents received some exposure from the chemical prior to masking.

Factor and MOE Selection

Eight factors and two MOEs were selected. We wanted to farm over blue speed, the obedience of the soldiers after they put on their protective mask, internal communication effectiveness, external communication effectiveness, the number of UAVs, the number of UGVs, JCAD sensitivity, and the marksmanship of the soldiers after they don their protective mask. The MOEs we decided on were mission accomplishment and time to accomplish the mission.

Additional data was needed to accurately depict mission accomplishment in addition to the Pythagoras MOE of arriving at the final way-point, or objective. So, we opted to collect data on the number of casualties from both chemical and kinetic weapons, the level of dosage for each blue agent, and the human agents' work output (modeled as fuel usage).

Figure 1: Model snapshot

Job Submission

We placed our factors into a NOLH spreadsheet that gave us our design. In conjunction, we placed our scenario file into the Tiller to interface with a computer cluster. The Tiller provided us with a study file that we manipulated our design of experiment into. At that point, time became a factor in actually receiving data back for our analysis and no model runs were conducted.

CONCLUSIONS

Team 2 set out with two goals in mind as stated earlier. We accomplished the goals with the building of our four scenarios and selecting the MOEs for use in ongoing research. We also concluded that an agent-based model is a feasible type of model for rapid modeling and analysis of chemical environments and SA.

Team 3: Communication Aspects In Urban Operations

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RESEARCH QUESTION

How do communication aspects affect operations in urban terrain?

OBJECTIVE

The main idea behind network centricity in military operations is to translate information superiority into combat effectiveness via creation and dissemination of a valid and relevant common operational picture. In order to achieve this goal, a number of preconditions have to be fulfilled. First and foremost, reliable communication lines have to be established both in gathering information about the current situation as well as in communicating a suitably aggregated (Common Relevant Operational Picture) CROP from the headquarter to the commander in the field. Therefore, the objective of our work is to investigate the impact of reconnaissance and communication quality on the outcome of a given military operation. Due to the nature of contemporary conflicts, we are especially interested in operations in urban terrain, which pose special challenges to reconnaissance as well as communication.

Apart from investigating the functional questions outlined above, we also seek to gain additional insights, both from modeling as well as from the contact to the international simulation and data farming community, to improve and advance the modeling and simulation toolkit ITSimBw, which is being developed at Fraunhofer IAIS under contract for the IT-Office of the German Armed Forces.

SCENARIO DESCRIPTION

The chosen scenario is based upon the battle of MOGADISHU on October 3, 1993. United States Army Rangers and the Army's Delta Force went on a mission to capture two warlords. Although the mission was successful, five American army UH-60 Black Hawk helicopters were shot down during the battle, two of them in the city area. In order to rescue survivors and to recover the dead, about 100 United States Army Rangers and Delta Force soldiers were pinned down in the city. In the Battle of Mogadishu, 18 soldiers were killed and several dozen were injured. Estimates put the number of Somali casualties at 500-1000 militia and civilians dead and 3000-4000 injured.

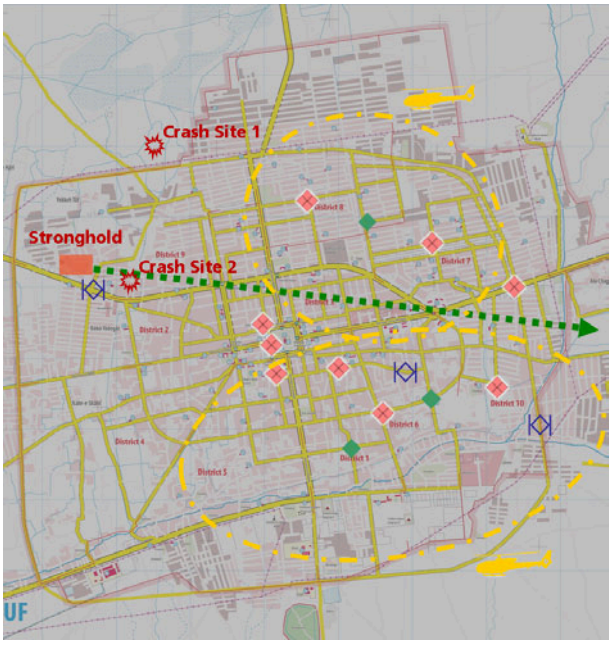

Figure 1: Scenario Overview.

Due to the current mission of the German armed forces in Afghanistan, the scenario plot is transferred to the city of MAZAR-E-SHARIF. In the derived

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vignette, the main focus lies upon safe return of a group of vehicles which had been involved in a raid on the stronghold of a militia leader to the blue base camp. This small convoy has to find a suitable route through the city. Dislocated red forces are spread throughout large parts of the town.

Moreover, civil informants aid red in spotting the blue vehicles. Thus, the blue HQ faces the challenge to deliver reliable reconnaissance of red forces to the commander of the vehicle group in a timely manner. To this end, it can use airborne reconnaissance means like helicopters or UAVs as well as lightly armored motorized ground patrols. Vital for the success of the mission are robust communication capabilities both in gathering observations as well as communicating locations of red forces to the leader of the vehicle column. An overview on the scenario situation is provided in Figure 1.

THE ITSIMBW III SIMULATION ENVIRONMENT

We used ITSimBw as the modeling and simulation environment for our investigations. In reaction to the challenges of network centric operations, the simulation system ITSimBw has been designed from the outset with a strong focus on the faithful representation of communication and IT aspects in contemporary warfare scenarios. Nevertheless, it is a general agent based simulation environment that can be effectively used in a large variety of different application domains including analysis and planning, CD&E, procurement management, education and training, and decision support.

The development of ITSimBw started in 2004 as a study carried out by Fraunhofer IAIS for the IT-Office of the German Armed Forces. The initial version was based on an agent simulation kernel that has been developed earlier. Before forming the basis of ITSimBw, it has been used in a variety of applications including traffic monitoring and forecast. Due to the lessons learned in the initial phase of the ITSimBw development and in order to incorporate cutting edge ideas from software design, a complete re-design and subsequent rewrite of the system has been carried out. At IDFW 14, this new simulation environment has seen its first real live usage.

ITSimBw's software architecture is now based on a service oriented paradigm which enables core functionalities, e.g. routing or line of sight computations, to be used as individual services. Furthermore, the whole system is now written in the JAVA programming language, which makes it easy to port to different computing platforms. Moreover, the excellent JAVA library support for remote object access and method invocation greatly facilitated the development of the new agent execution environment which can be spread among CPUs in a cluster, thus enabling distributed processing of simulations.

Another important feature of the new version of ITSimBw is the incorporation of LAMPS, the graphical description language for scenarios and agent behaviors which replaces the former rule language interpreter for the programming of agent behaviors. Thus the actions performed by agents in the simulation can now be specified via a graphic programming language that is based on high-level Petri nets.

An additional important driving factor for the system redesign is the improvement of usability. To this end, a number of steps have been taken in the new version. Among those is the development of a variety of new editors for scenarios, agents, and agent behaviors as well as the consequential incorporation of drag and drop facilities, to name only a few.

AGENT MODELING

In order to investigate the given scenario, a number of agents had to be modeled. In the following section, we will briefly describe them together with their major behaviors.

Environment

ITSimBw greatly emphasizes consequential agent based thinking in modeling. Therefore, not only the acting entities in a given scenario, but also the environment, are modeled as agents. In our example, the environment agent contains in its states the background – a city map of MAZAR-E-SHARIF, as well as a roadmap for all major roads in the form of an entity relation graph. In this representation, nodes that are placed at junctions or bends are linked by straight edges which form road-parts. All agents in the scenario that are able to move on their own accord can use that roadmap in order to make their routing decisions when traveling to their designated goals.

Figure 2: A Close-Up of the Background and the Roadmap.

Headquarter

As has already been stated in the scenario description, generation and dissemination of a valid and current CROP is a key factor for mission success. We have therefore modeled a headquarter agent that receives the sight information of all blue agents – the motor convoy, the patrols, and the reconnaissance helicopters and merges them into a list of spotted red agents. This list is then returned to all blue agents as the current CROP. Moreover, the headquarter can send command messages to the blue agents over voice radio connections. We thus have two main lines of communication, data streams and voice radio. They are modeled as depicted in Figure 3:

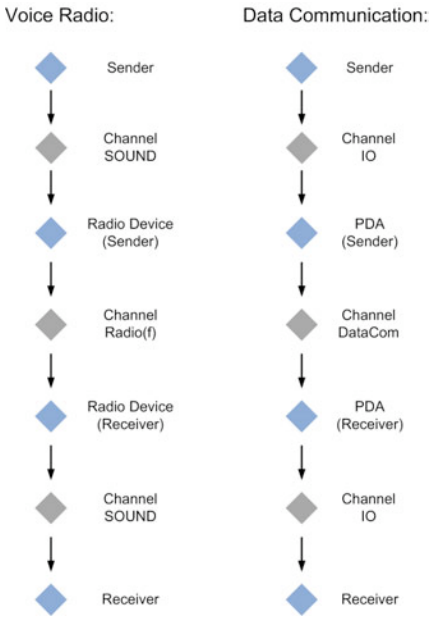

Figure 3: Communication Modeling.

As one can see from this diagram, we have individual agents modeling the communication devices such as PDAs for data, and voice radios. Moreover, the communication channels themselves are modeled as agents. In order to represent the communication acts as faithfully as possible, we even included the channels *Sound* and *IO* in our modeling. For later investigations, disturbances and malfunctions can be modeled individually for each communication device and channel.

Motor Convoy

One of the most important agents in the simulated scenario is the line of vehicles that starts out at the militia leader's stronghold moving towards the safe base camp at the airport. For sake of simplicity, we have modeled this convoy in aggregated manner, i.e. the complete line of vehicles is represented by a single agent. It senses its environment via the behavior *view*, which uses a voxel-space representation of the environment together with all other agents to compute the visibility information. Moreover, it contributes to the CROP generation by sending its individual view to the headquarter over the data channel outlined above. In return, it receives the merged CROP information from the headquarter, also via data stream. In order to fulfill its goal, it has to find a safe route towards the base-camp, avoiding red-forces – in particular the road-blocks – at all costs. Therefore, its standard route finding algorithm has been augmented in such a way that it avoids edges in the road-graph, on which known red unit are positioned. Furthermore, it has the ability to engage red units, when contact cannot be avoided.

Reconnaissance Helicopters

In order to provide airborne reconnaissance, two helicopters are included in our scenario. The respective agents view their environment and send the corresponding information to the headquarter via data link. They move on designated patrol routes that cover specific areas of the city.

Ground Patrols

Apart from the helicopters, blue's reconnaissance also has a ground component, given by two patrols which are comprised of two lightly armored infantry vehicles each. Each patrol is – like the convoy- modeled as an aggregated agent. The patrols follow designated routes through the city. They contribute to the CROP in the same way as the airborne reconnaissance assets. Moreover, they have the ability to engage enemy units, when being attacked.

Militia

Small groups of dismounted red militia forces are dispersed throughout the city. Each group is modeled as an aggregated agent representing the respective group. Additionally to the standard behaviors for routing and moving on the road-net, they have the capability to engage blue with light hand weapons. In case that one of them spots the convoy, it sends a message that affects the setting of a dynamic roadblock. Moreover, they have the capacity to "hear" the sound form other engagements and to move in that direction.

Civilian Informants

In addition to the militia forces, we have also modeled civilians that are sympathetic with the red side. Like the militia, they can send messages that lead to the placement of dynamic road-blocks. Moreover, they also follow the direction of combat noise in order to investigate the situation. They are, however, unarmed, and they are not attacked by blue forces.

Road-Blocks

We have two kinds of road-blocks in our scenario. The first one is static in the sense that instances of this kind are positioned right from the outset of the simulation. The second kind is dynamic, i.e. instances of this class are positioned during the course of the simulation, reacting on where red forces or civil informants spot the blue vehicle line. The road-blocks in our scenario had high fire power corresponding to multiple machine guns. Furthermore they were impossible to destroy by blue vehicles.

INVESTIGATIONS

During IDFW 14, we have defined positions and patrol routes for the reconnaissance helicopters and ground patrols. Initial positions for the fixed roadblocks as well as promising locations for their mobile counterparts were identified by trial simulations.

At the workshop, we used the latest version of ITSimBw, which, at that time, was still in a rather early phase of development. As a consequence, our modeling work did not proceed as fast as anticipated beforehand. Time constraints prevented the set-up of data-farming runs to investigate the role of communication quality. Instead, only the two extreme points of the spectrum, perfect communication quality and no communication at all could be examined in simulation runs. In the first case, the optimal result with respect to our MOE – number of vehicles that safely return to the base camp – was achieved. In the latter case, however, a complete loss of the vehicle column occurred as it was unable to avoid the line of fixed roadblocks.

CONCLUSIONS

Despite the fact that we were unable to conduct the data farming experiments in the breadth that was originally intended, a lot of interesting insights in our scenario have been gained. Moreover, we gathered a variety of suggestions for the further improvement of our simulation tool ITSimBw, especially with respect to additional advances in usability.

Team 4: Exploring Sharing Behaviors

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INTRODUCTION

The U.S. DoD (OASD/NII) Command and Control Research Program (CCRP) has sponsored the design and development of a software environment for conducting human-in-the-loop experiments focused on information- and social-domain phenomena. This experiment has come to be know as the ELICIT Experiment (Experimental Laboratory for Investigating Collaboration, Information-sharing, & Trust). Over the course of several Project Albert International Workshops, EBR has strived to create and improve a simulation version of the experiment. Utilizing the NetLogo agent-based modeling environment, we have built upon prior work, augmenting the model to more explicitly represent cognitive and collaborative processes. During this week, Ms. Danielle Martin, Tony Costa, Karina Malvaez-Buenrostro, and Fidencio Vargas-Davila, have worked to study how sharing behaviors such as posting, direct sharing, hoarding, and processing affect an organization's performance in solving a simple cognitive task.

In the scenario participants received information about a future attack. The information is parsed into four question categories and the participant's mission is to gain sufficient knowledge related to each topic to solve the four questions. These information facts are periodically distributed and then shared via one on one interactions or website broadcasts. The network's objective is to solve the four task questions by combining and sharing the set of information facts. Participant actions are constrained by the network structure. Any given participant's awareness depends on what combination of facts they have seen.

Analysis Summary

Of the sixteen variables farmed throughout the workshop, a participant's propensity to share information had the greatest overall impact on solution time. The amount of information an agent is capable of processing on any given time step also proved to be influential over solution time. Other network parameters such as connectivity, symmetric communication links and homogeneity of the agents had little influence over the solution time.

When exploring the overall knowledge of the participants, the Edge organization has a high level of awareness of the solution space. The group was surprised to learn that network connectivity, the rate at which an agent processes information, and the quantity of information an agent can process have little impact on knowledge of the solution. Perhaps additional runs will clarify this point. Surprisingly, behaviors such as reciprocation and targeted sharing had only a small effect on the MOEs.

Immediate follow on activities include continuing to refine and analyze the model, and the redesign of the experimental design points to further explore the effects of the model parameters. In future efforts we are interested in looking for additional methods of representing the facts and the information quality levels associated with each. As a long term goal, we plan to inform development and execution of associated human experiments, and leverage information and data from ongoing experiments. Modeling human social and cognitive processes is a challenge. We hope that by exploring the data collected from the live experiment, our team will be able to more accurately reflect these processes in an agent-based modeling environment.

Additional information regarding the ELICIT Experiment can be found at:
http://www.dodccrp.org/html3/elicit.html

Team 5:
System-of-Systems Test Planning

TEAM 5 MEMBERS

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INTRODUCTION

Joint operations have become the mainstay of warfighting. Force Transformation requires the Test and Evaluation (T&E) community to place a much greater emphasis on testing joint warfighting capabilities. A unique challenge in assessing the effectiveness and suitability of systems in the joint environment is the multitude of possible interactions and outcomes in a system-of-systems construct. New and developing acquisition programs rely on interfaces with existing or future systems, quite possibly from separate services, to achieve mission success. Because of resource constraints and the complexity of conducting live, virtual, and constructive testing in a joint mission environment, the Joint Test and Evaluation Methodology (JTEM) program is interested in determining if analytical techniques, like Modeling and Simulation (M&S), can be applied to understand the relationship between system-of-systems performance and joint mission effectiveness. As a proof of concept for investigating this possibility, Network Enabled Weapons (NEWs) was chosen as a framework for further study. The NEW concept centers on the ability to identify, engage, and attack moving targets, within moments of their identification, through the use of in-flight target updates (IFTUs) across a Weapon Control Network (WCN).

As acquisition systems like NEW are required to conduct more testing in the context of a joint mission, it will be essential that these tests be as efficient and useful as possible. With the complexity of the joint test environment, M&S is one of the most effective tools to help understand the environment, design an efficient and useful test, and to help investigate robust possibilities in the use of forces to accomplish operational tasks. This research used an agent-based distillation, which is a type of computer simulation, to model the critical factors of interest in combat without explicitly modeling all of the physical detail. Agent-Based Modeling (ABM) refers to a type of simulation made up of agents (or entities) that behave autonomously. These agents possess simple internal rule-sets for decision making, movement, and action. When combined with other entities in the model and subjected to stochastic conditions, the agents interact in ways that are often reflective of large-scale system behavior.

As with many complex endeavors, military conflicts typify an environment of autonomous or semiautonomous agents, uncertainty in behavior and outcomes, a wide range of operational inputs, and complex interactions between entities. The combination of ABM with Data Farming offers an exploratory, analytical approach to broadly consider uncertainties associated with elements of warfare that might otherwise be too costly or time intensive to study with other means.

Description of Scenario

The base network configuration for this research will include three active nodes—the strike aircraft, the weapon, and the "weapon controller." The weapon controller can refer to either the strike (i.e., launch) aircraft or a third-party Joint Terminal Attack Controller (JTAC). A multitude of possible mission scenarios exist, but an example of a particular

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construct is provided in Figure 1. The lightning bolts represent networked communications between the entities involved. Through communications with the Combined Air Operations Center (CAOC), an identified target gets assigned to a mission typical of the concept of operations for a NEW. During flight of the weapon, target location updates are passed to the guidance system of either the aircraft or the NEW in order to maneuver the munition to the target. This networked capability is what enables the engagement of moving targets without using existing technologies like laser-guided identification or camera-guided flight.

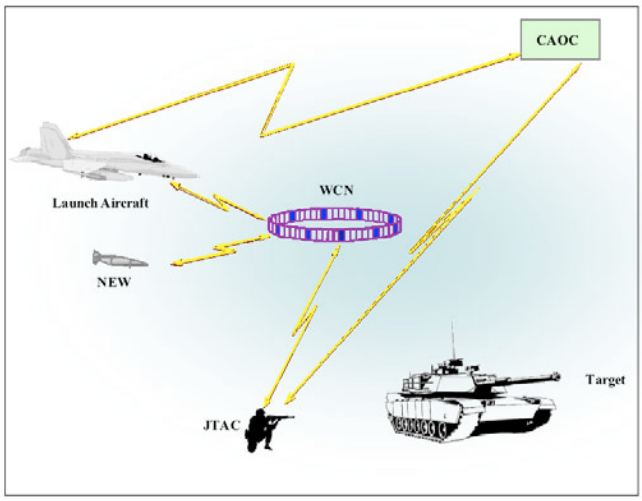

Figure 1: Guiding a NEW to the Target

Experimental Design

Rather than taking a "trial and error" approach to experimental design (be it live or in the M&S environment), researchers often use specialized techniques to organize the myriad of possible parameter settings. The overall objective of the design is to maximize the information gained from a limited number of experimental runs. The use of orthogonal, or nearly orthogonal, Latin hypercubes with excellent space-filling properties enable efficient exploration of simulation models. Unlike traditional factorial designs, which test only a few factors at a minimum number of levels, a space-filling design explores a broad landscape of factor settings.

The base scenario developed for the workshop consisted of six agents (Launch Vehicle, NEW, Mobile Target, Ground Observer, Weapon Control Network, Command & Control Network) and 17 factors. The Design of Experiments used the Nearly Orthogonal Latin Hypercube (NOLH) approach—resulting in 129 design points. Due to unforeseen difficulties in computing resources, we were limited to 10 replications for each design excursion. Our intended measures of performance were single-shot probability of kill and the amount of time between target identification and kill, for those engagements resulting in success.

RESULTS AND ANALYSIS

Our most profound results during the workshop dealt with understanding of the model itself, as opposed to the post-run data analysis. Using the model's Graphical User Interface visualization mode, we were able to notice several anomalies related to either physical interactions of the agents or operational inaccuracies. We also explored and documented a myriad of operational "What if?" discussions, which may provide insight to concerned parties, irrespective of any simulation results. We finished the week with a much greater understanding of the model's capabilities and limitations and a healthy list of improvements required before using the model for in-depth analysis.

Follow-on Research

Further development of the model was completed after the workshop in support of the author's Master's thesis at NPS. Using the NOLH experimental design techniques, the computer model was run many tens of thousands of times, with each parameter having 257 settings varied uniformly over operationally viable ranges. The results were analyzed to determine the critical parameters required for mission success. In the case of a single moving target, indicative of a wheeled or tracked vehicle, the analysis indicates a significant time-distance interaction between the sensor range of the ground-based JTAC and the speed of the target. Specifically, when the target speed is less than 13.2 meters/sec (approximately 30 mph) and the JTAC sensor range exceeds 2,117 meters, the model indicates an 80% improvement in target kills, regardless of the other parameter settings. Moreover, when a combination of these two parameters is constrained across a realistic, but time-sensitive range, the model indicates that the amount of time taken by the decision authority to issue a Close Air Support (CAS) request and the speed at which the launch aircraft flies to engage the target provide the most improvement in mission success.

To test the system's ability to engage a subsequently identified high-value target (HVT)—

possibly with a redirect of a NEW already in flight—scenarios were run with two targets in the battlespace. The second target possesses the characteristics of a dismounted individual on patrol. The model indicates different results for the kill rate of the HVT, depending on whether or not the launch aircraft contains a load of two NEWs or just one. In the case of one weapon, for a JTAC sensor range of less than two kilometers, the kill rate of the HVT is shown to improve by nearly 82% if the In-Flight Target Update (IFTU) interval is less than 50 seconds. In the case where two weapons are available, the most important factors affecting the HVT kill rate are specific to the weapon itself. Namely, if the impact radius exceeds 5.4 meters and the probability of kill for a target within the blast radius is greater than 0.92, then the overall kill rate approaches 95%.

SUMMARY OF FINDINGS

While relatively simple in design, the simulation model provides a realistic depiction of operational scenarios and the interactions of systems within the NEW construct. Over the course of this research, the author consulted with JTEM personnel and subject matter experts within the NEW development community to discuss model functionality and the ranges of settings for model parameters. The author and the model co-developer worked through numerous iterations of programming and debugging over the course of six months in order to refine the model and improve its performance.

CONCLUSIONS

The results of the analysis determined key interactions in NEW system-of-systems performance. Additionally, when considered in context of the scenarios developed, the model provides insight for program managers trying to understand the required performance characteristics of systems in development. Most importantly, the research indicates that ABM, especially when combined with efficient design principles, can yield a method to quickly analyze a complex system-of-systems construct and provide JTEM with a framework for effectively conducting testing in a live environment.

Team 6: Joint Capability Metamodel-Test-Metamodel Integration with Data Farming

TEAM 6 MEMBERS

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INTRODUCTION

US adversaries are continuously seeking new ways to threaten US interests at home and abroad. In order to counter these threats, now more than ever, commanders must seek to leverage existing and emerging joint capabilities effectively in a variety of unique contexts. Achieving mission effectiveness in today's joint operational environment demands robust synergy among a wide array of mission-critical Service systems and capabilities.

Previously, forces and platforms were developed upon specific threat and scenario constructs. Requirements have often been developed, validated, and approved as stand-alone Service solutions to counter specific threats - not as participating elements in an overarching system-of-systems or joint capability.

Now, joint operations have become the mainstay of warfighting. The systems and capabilities warfighters employ must be tested and evaluated in a joint mission environment.

The challenge program managers and test organizations face is that effective testing and evaluation is becoming more difficult as individual platforms are increasingly being integrated into a complex joint mission system of systems. Ensuring that we test like we fight is the challenge Joint Test and Evaluation Methodology (JTEM) is working towards during this International Data Farming Workshop (IDFW).

JTEM IDFW 14 OBJECTIVES

Specific objectives of Team 6 sessions during IDFW 14 included:

1. Technical interchange involving the CEM (Capability Evaluation Metamodel) measures framework, data farming, efficient design of experiment, and other selected visualization, modeling, analysis, and simulation (VMAS) capabilities relevant to JTEM.
2. Initial characterization of an Integrated Fires capability area using the CEM for further use in the Data Farming for Test Planning effort.
3. Front-end systems engineering of a CTM (Capability Test Methodology) test design analysis environment incorporating an Integrated Fires capability use case and candidate VMAS solutions. This included review and refinement of the CTM Develop Test Design process descriptions.

JTEM CAPABILITY EVALUATION

A critical piece of JTEM's efforts entails the development of methods and processes to enable the evaluation of system of systems performance as it pertains to capabilities supporting joint missions. As part of this endeavor, a Metamodel-Test-Metamodel approach is being developed as part of JTEM's CTM. In order to structure the underlying business rules and concepts in the CTM's evaluation thread, a CEM is being developed. The CEM is called a metamodel due

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to its integration across multiple Department of Defense policies related to joint capability and due to its embedded use of design of experiment (DOE) models to describe the CTM test space. The CEM provides the underlying information concepts and relationships to dynamically model and distill the test space into a test design, drive the analysis plan, and systems engineering design of the live virtual constructive distributed environment.

An integrated visualization, modeling, analysis, and simulation (VMAS) environment is required to evolve CEM test design structures. Potential VMAS catalysts include test design visualization, efficient design of experiments, simulation model classes and hybrids, as well as simulation analysis and visualization techniques. Moreover, functional and integration requirements to enable effective and suitable distillation of a capability's test space as part of a capability test design need to be taken into consideration.

THE CAPABILITY EVALUATION METAMODEL

In order to provide conceptual consistency and an underlying business rule structure for the CTM, JTEM is employing an ontology approach. An ontology can be defined as "an explicit formal specification of how to represent the objects, concepts and other entities that are assumed to exist in some area of interest and the relationships that hold among them." [1]. In keeping with this definition, the ontology supporting the CTM evaluation thread incorporates a JTEM lexicon and capability evaluation metamodel (CEM) to provide underlying conceptual definitions and relationships for the CTM [2]. The JTEM lexicon is a cross-domain dictionary of CTM-relevant Department of Defense (DOD) terminology and definitions. Authoritative DOD sources are used, where possible, for JTEM terms and definitions. When modifications or additional terms are needed for the CTM, these are noted in the lexicon as proposed by JTEM, requiring feedback from JTEM to authoritative DOD lexicon sources.

The CEM provides a conceptual model to relate key CTM test and evaluation lexicon concepts, including capability, system of systems, mission, task, and various types of measures. Key concept hubs of the CEM are represented in Figure 1 as boldly outlined rounded rectangles. A central CEM concept hub is Joint Capability and it is expanded in Figure 1 to show its main relationships. Capability is defined in the DOD Joint Capabilities Integration and Development System (JCIDS) instruction as "the ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks" [3]. This definition is reflected in the CEM's Joint Capability hub relationships.

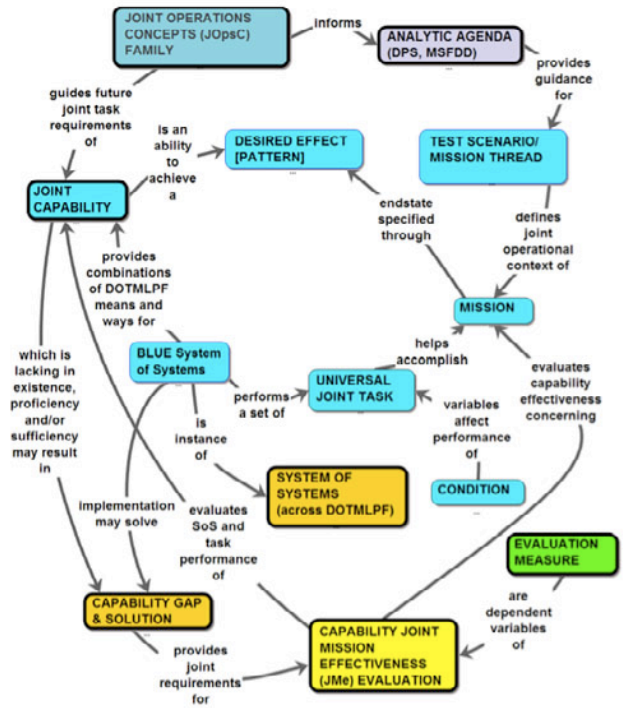

Figure 1. Capability Evaluation Metamodel (CEM) Concept Hubs

A Blue (Friendly) System of Systems (SoS) provides the means and ways for a Joint Capability to perform a set of Universal Joint Tasks. Such Universal Joint Tasks help accomplish Missions, whose Endstate is specified through Desired Effects. The JCIDS capability definition also mentions Conditions, which can be related as variables (e.g., environmental, disparate forces) affecting the performance of Universal Joint Tasks. Although not mentioned in the JCIDS capability definition, the concept of mission is important to relate Universal Joint Tasks to Desired Effects. Joint Capability hub relationships complete with Joint Capability being an ability to achieve Desired Effects. The Blue SoS identified in the Joint Capability hub is an instance of the System of Systems concept hub, which incorporates non-materiel and materiel aspects across the resource construct of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF).

The joint operational context for evaluating Mission Desired Effects is to be defined by a Test Scenario or Mission Thread and guided by authoritative sources from the DOD Analytic Agenda concept hub involving Defense Planning Scenario (DPS) and more detailed Multi-Service Force Deployment Document (MSFDD) descriptions. DOD also develops the Joint Operations Concepts (JOpsC) Family, including subordinate Joint Operating Concepts (JOC), supporting Joint Functional Concepts (JFC), and detailed Joint Integrating Concepts (JIC) that amplify a portion of a JOC or JFC. JOpsC Family Concepts inform the development of Analytic Agenda products and guide joint task requirements of future Joint Capabilities.

JTEM USE CASE EXERCISE

Based on the Joint Capability hub, a use case was developed to instantiate the concepts presented in the CEM. This use case provided a Joint Operational Context for Test based on an Integrated Fires (IF) joint capability provided by two systems (Network Enabled Weapon [NEW] and a Fire Support Platform [FSP]) within a Systems of Systems (SoS). The mission of the IF capability in the use case is to block the advance of enemy forces into a main Joint Forceable Entry Operations (JFEO) operations area. This IF use case is graphically presented in Figure 2 as a DoDAF OV-1 view that incorporates Mission, Effects and End State Attributes, the SoS structure and the tasks that provide the contribution to achieving the mission end state.

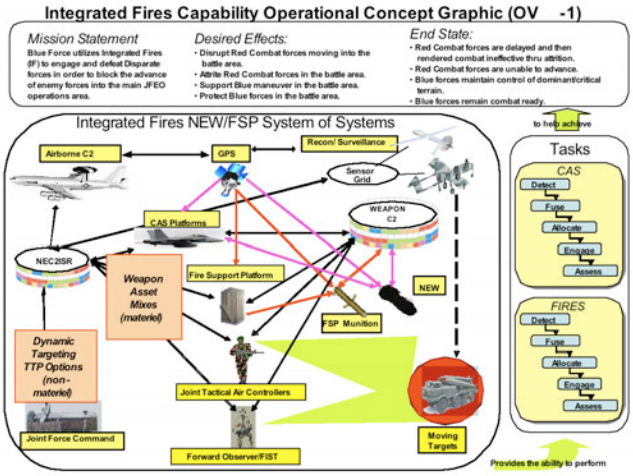

Figure 2. Integrated Fires OV-1 View

Team 6 participants presented and used the IF capability use case to populate CEM structures, which define input factors and levels of a capability test space. These test design dimensions are mission, system of systems, and mission conditions (including disparate force and environmental conditions). This exercise of applying joint mission-level capability concepts to the structure of an efficient design of experiment (DOE) [4] provided a basis for further configurations of a CTM test design.

CTM REFINEMENTS

During working sessions, Team 6 participants also reviewed and discussed refinements to initial modeling sections of the CTM. Based on this discussion, JTEM has proposed refinements to the

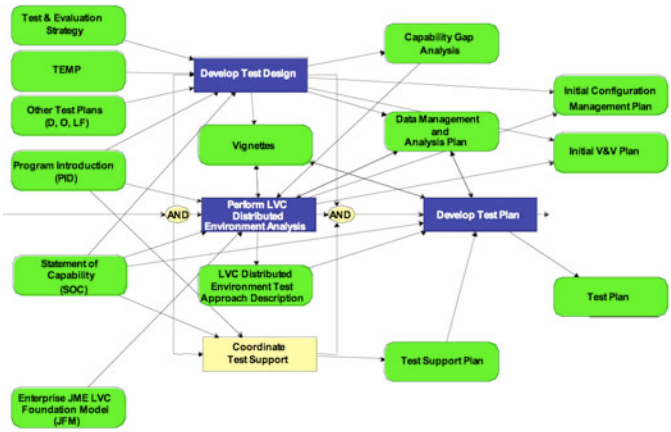

Figure 3. CTM 2: Plan Test Phase

CTM and added detail at lower process levels. The majority of the changes to the CTM were incorporated into the second step of the CTM process, the Plan Test phase.

As shown in Figure 3 below, the plan test phase takes test concepts contained in the program introduction document (PID) and statement of capability (SOC) and further develops them into a test plan. The Test Planning process includes developing the test design, performing Live, Virtual and Constructive (LVC) distributed environment analysis, and coordinating test support. Developing the test design involves producing test vignettes and a data management and analysis plan (DMAP). As part of the plan test phase, the parallel process of performing LVC distributed environment analysis produces a LVC distributed environment test approach description. The final part of this parallel process is test support coordination. This step ensures that the test has all the necessary products and range facility support and

enables the development of the test support plan. Through completion of the development of the test design, performing the LVC distributed environment analysis, and coordinating the test support plan the test manager is able to develop the test plan. The Develop Test Plan process then synthesizes these processes to develop the overall Test Plan, which incorporates all identified products from this phase.

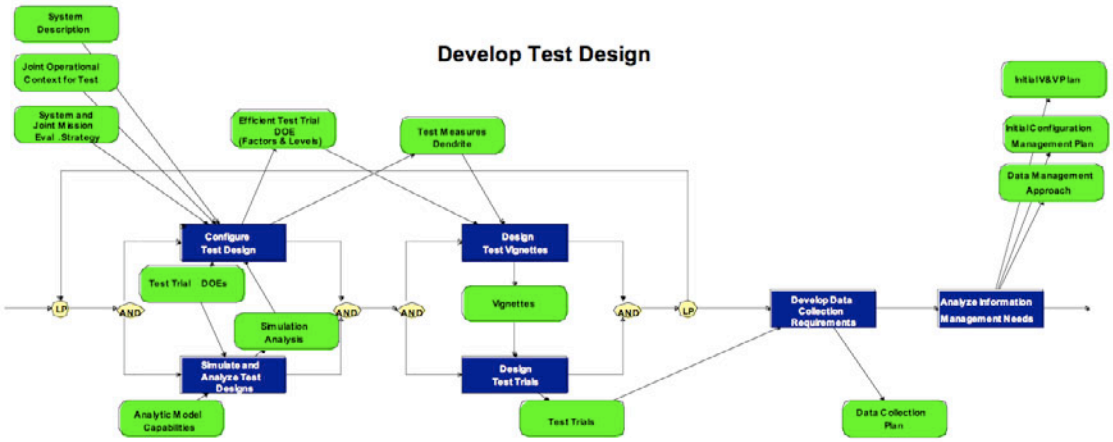

Figure 4. Updated CTM.2.1: Develop Test Design

As a result of IDFW discussions, the Develop Test Design process in the CTM Plan Test phase was revised. This revision further incorporated initial metamodeling and simulation of the Metamodel-Test-Metamodel evaluation approach into the CTM. The revised Develop Test Design process, shown in Figure 4, includes initial processes called Configure Test Design and Simulate and Analyze Test Designs. During Configure Test Design, it is necessary to analyze System Descriptions, the System and Joint Mission Evaluation Strategy (including the test scenario), and the Joint Operational Context for Test. Using these products the program manager can configure an initial test design involving CEM test space dimensions and CEM evaluation measures. The Configure Test Design produces Test Trial Design of Experiment (DOE) output. These Test Trial DOEs are then analyzed in the Simulate and Analyze Test Designs process using Analytic Model Capabilities to better determine suitability of candidate test designs. The Simulate and Analyze Test Designs process produces Simulation Analysis as an output. This simulation analysis is used to help validate test design DOE configurations. If necessary, the test design is then refined, based on the Simulation Analysis and subject matter expertise. These two processes can be iterated until an Efficient Test Trial DOE is produced, including test factors and levels. These processes also produce a Test Measures Dendrite, which contain test response measures.

Once the test design is well developed, Figure 4 shows the processes to Design Test Vignettes and Design Test Trials. From vignette descriptions, test trial matrices are created that specify levels for independent test factor variables and dependent test data collection measure variables. The Test Vignette and Test Trial output provide analysts with the ability to Develop Data Collection Requirements and produce a Data Collection Plan. The final process of developing the test design is the Analyze Information Management Needs process, which produces an Initial Verification and Validation plan, an Initial Configuration Management Plan, and an initial Data Management Approach.

CTM VMAS CATALYSTS

Team 6 participants also discussed an integrated set of VMAS catalysts required to evolve CEM test design structures during the CTM's Plan Test phase. Potential VMAS catalysts include; test design visualization, statistical design of experiments, simulation model classes and hybrids, as well simulation analysis and visualization techniques which can fill capability evaluation gaps in the front-end part of the CTM evaluation thread.

Dr. Kelton asserted that there is an early need to identify critical output measures (metrics) to guide development of models and decision criteria. He discussed automatic specification of empirical input probability distributions, extant simulation models, the need to reduce the dimensionality of the heavy factorial loads that will be associated with a SoS test matrix to foster more efficient, low resolution model designs and the limitations of traditional polynomial-

regression-based metamodels. There are several classes of empirical input probability distributions (bounded, infinite right tail) that could aid in rapid modeling and re-modeling as additional data become available. There is the possibility to use extant simulation model as a tool to guide relative efforts on the various inputs. These inputs probably are not all equal and can use simulation as a sensitivity-analysis tool to assess relative importance.

Dr. Kelton discussed the miss-use of random numbers in stochastic simulations. Almost always you can get better simulation results (lower variance with no more computing) if you use random numbers more smartly. This could be largely automated, with the right software design (which doesn't exist yet), so users wouldn't have to think about it or do anything differently.

The basic idea Dr. Kelton would like to see implemented in simulation software using random-number generators (RNGs) is to foolproof their implementation, in three steps:

1. Use a modern underlying RNG with astronomical cycle length (like 10^57, not the measly 10^9 in old RNGs that are still, for some mysterious reason, in wide use) and excellent tested statistical properties. Such RNGs have existed for approximately 8 years.
2. Provide starting seeds for widely separated streams within the RNG. The stream number should be user-definable, but in addition to that the software should automatically increment the random-number stream each time a source of randomness is dropped into the model.
3. Within each stream, provide widely separated substreams that are automatically incremented for each statistical replication for all streams (i.e., substream 1 within all streams for replication 1, substream 2 within all streams for replication 2). With the right underlying RNG and the right seeds, exhausting even a substream (let alone a stream) would take thousands of centuries on today's computers (and, even under Moore's law, it will be a few hundred years before we need to worry about it again).

What this would do (automatically) for users goes a long way toward "synchronization" of random-number use in simulations. In simulation projects involving comparison of several competing policies or alternatives, which is most simulation projects, this results in the reduction of estimates in the difference between policies and alternatives, sometimes dramatically. Therefore, you get more precise results with no extra computing needed (extra computing will always reduce variance). With the large combat simulations, where a single replication can take hours, this could really help run times.

Potential CTM simulation output analysis techniques were also discussed. Dr. Kelton pointed out that when dealing with capability use cases involving complex adaptive systems (CAS), there are limitations in use of traditional polynomial-regression-based metamodels for output analysis. This is due to the need to identify potentially important response discontinuities or "tipping points" in such systems. LTC Schamburg reviewed his Advanced Response Surface Methodology (ARSM) approach to simulation analysis, which has relevance to CTM analysis problems during the Plan Test phase [5] and addresses discontinuities so they are not simply “paved over” by the data plot. These problems involve a larger number of input variables, multiple measures of performance, and complex systems relationships. The ARSM approach capitalizes on the underlying learning philosophy of the traditional RSM while benefiting from other knowledge discovery concepts and data mining techniques. Furthermore it does not require the restrictive assumptions of the traditional RSM nor does it restrict the analyst to the traditional RSM techniques.

Dr. Sanchez presented a candidate comparative analysis technique to address the multiple response analysis problem which occurs during CTM simulation analysis. Once each test measure response is analyzed with respect to test input factors and levels, a matrix can be created to compare results across multiple responses. An example was given for the comparison of two measures, where the following cases could occur: Test factor treatments could just show significance for a single response, or treatments could show significance for both responses. If a factor is significant for both responses, the treatment levels could agree, which would not require further analysis, or disagree, identifying where further tradeoff analysis is needed.

CONCLUSIONS

There are innovative techniques and methodologies that fit within the structural umbrella of the CTM. These techniques are currently being incorporated into CTM test planning processes. Data Farming techniques can provide an important contribution to the definition and evaluation of CTM metrics through Design of Experiment (DOE) techniques and evaluation methods such as ARSM.

The way ahead is to continue development of the efficient DOE relative to the Integrated Fires use case developed as part of the JTEM test sequence. VMAS catalysts and best practices will be identified and incorporated into the JTEM Analyst Guidebook and models designed using efficient DOE and the IF use case will be run during IDFW15.

REFERENCES

[1] Ontology. Dictionary.com. *The Free On-line Dictionary of Computing*. Denis Howe.

http://dictionary.reference.com/browse/ontology (accessed: December 15, 2006).

[2] Dryer, D., Bock, T., Broschi, M., Beach, T. 2007. DoDAF Limitations and Enhancements for the Capability Test Methodology. In *Proceedings of the Spring Simulation Multiconference*, 170-176. Norfolk, VA, 25-29 March.

[3] Department of Defense. 2005. "Joint Capabilities Integration and Development System. Chairman of the Joint Chiefs of Staff Instruction, CJCSI 3170.01E." Washington, DC, 15 May.

[4] Sanchez, S. M. 2005. Work smarter, not harder: Guidelines for designing simulation experiments. In *Proceedings of the 2005 Winter Simulation Conference*, eds. M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, 69–82. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers. Available via http://www.informs-sim.org/wsc05papers/009.pdf [accessed April 24, 2007].

[5] Schamburg, J & Brown, D. 2004. A generalized multiple response surface methodology for complex computer simulation applications. In *Proceedings of the 2004 Winter Simulation Conference*, eds. *R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters*, 958-966. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers. Available via http://www.informs-sim.org/wsc04papers/122.pdf [accessed April 24, 2007].

International Data Farming Workshop 14

Plenary Sessions

Planting the Seeds of Learning

Following is a list of the keynote and plenary sessions at IDFW 14. These presentations, as well as team in- and out-briefs, team reports, models and data can be found on the IDFW14 CD or website (see inside back cover for details).

Keynote: The Centro de Estudios Superiores Navales: Interest in Data Farming and Building Long-Lasting Relationships

VADM Moises Gomez Cabrera

President, Centro de Estudios Superiores Navales, Mexico

VADM Cabrera described the Centro de Estudios Superiores Navales (CESNAV), which is an education center with the mission to deliver postgraduate education to Mexican Navy personnel, national federal government officials, and international military guests. CESNAV supports the diffusion of naval doctrine and the promotion of maritime culture, through research, academic, and dissemination activities related to National Security, Defense, and Naval Operations. The CESNAV vision is to be a cutting edge center for naval education of high academic quality, forming strategic minded leaders able to predict threats to National Security and Defense and act capably and effectively in the decision making process for the achievement of national objectives.

In order to enrich the experience of their respective students, faculties, and staffs and to enhance the long-standing relationship between the Mexican Navy and the United States Navy, VADM Cabrera stated that CESNAV is interested in establishing a relationship with the Naval Postgraduate School and the SEED Center, to engage each other on a broad range of issues relevant to professional military education.

Keynote: The Advanced Response Surface Methodology (ARSM)

LTC Jeff Schamburg

US TRADOC Analysis Center, Monterey

Introduction to the Advanced Response Surface Methodology (ARSM); Overview of TRAC-Monterey; Future TRAC-Monterey Research Directions of Interest

Data Farming for New Members

Gary Horne

Naval Postgraduate School, US

An expansive introduction to the concepts and methods of Data Farming.

Pythagoras Version 1.10

Zoe Henscheid

Northrop Grumman Mission Systems, US

Keynote: Col Joseph Smith - *USMC MC Combat Development Center*

The ITSimBw Simulation Environment
Thomas Zöller
Institut Intelligente Analyse und Informationssysteme, Deutschland

PAX 3.0: Flexible Toolbox for the Simulation of Peace Support Operations
Thorsten Lampe/Gunther Schwarz
EADS Deutschland GmbH

See " PAX: Designed for Peace Support Operations" on page 43 for an overview of this talk.

Joint Dynamic Allocation of Fires and Sensors (JDAFS)
Darryl Ahner
U.S. Army Training and Doctrine Command Analysis Center

Workshop Announcement and Discussion: Validation Methodology for Agent Based Simulations
Zoe Henscheid
Northrop Grumman Mission Systems, US

Simulation Support to the Warfighting Commander
MAJ Jon Roginski
CNO SSG, US

SEED Center for Data Farming Overview
Tom Lucas and Susan Sanchez
US Naval Postgraduate School

Social Modeling for Representing Urban Cultural Geography in Stability Operations
Jack Jackson
U.S. Army Training and Doctrine Command Analysis Center

Educating the Next Generation of Scientist
MAJ Jon Roginski
CNO SSG, US

Validation of the INCIDER model
Dave Dean
Dstl Land Battlespace Systems, UK

Team 7: Applying Automated Red Teaming in a Maritime Scenario

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INTRODUCTION

With shipping at the heart of the global economy, maritime security is required to ensure freedom of the seas and to facilitate freedom of navigation and commerce. It is therefore important for nations to stand united and share in the responsibility for maintaining maritime security, when faced with an array of threats from the terrorists and criminals. This study will focus on one aspect of the maritime security - key installation (KINs) protection.

AIM

This study aims to:

- Explore and determine the worst-case scenarios for Blue through Manual Red Teaming (MRT) and Automated Red Teaming (ART)[1];
- Evaluate the usefulness of MRT and ART in Blue Ops Planning.

DESCRIPTION OF SCENARIO

Initial Scenario Set-up. In this baseline scenario, the Blue forces conducted coastal patrols to guard against threats on key installations (KINs). Each of these KINs was represented as a Coastal Surveillance Radar (CSR) equipped with minimum level of self-protection. The Red forces will attempt to penetrate the Blue defense and inflict damages on the Homeland, using various approaches. Any damages to the coastline will deal a severe psychological blow to the Blue defense force. The initial set-up of experiment was as shown in Figure 1 below.

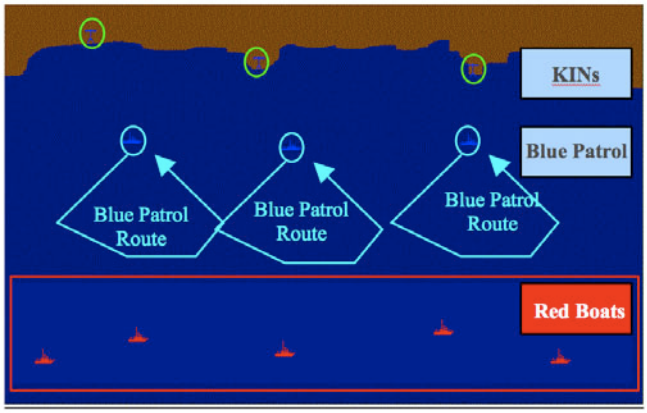

Figure 1: Initial Set-up of Experiment

KEY ASSUMPTIONS

The following key assumptions were made for this scenario:

Area of Operations (AO). The AO was assumed to be in coastal waters away from the sea lines of communications (SLOC) and main shipping traffic. As such, the neutral shipping was not modeled.

Environmental Conditions. It was assumed that the operations were conducted in dark hours with clear weather conditions (i.e. no rain and no moonlight) and calm sea state.

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1 ART was developed by DSO-ORL to find an optimal solution for the Red team (the worst-case scenario for Blue team) in a two-sided scenario, using evolutionary algorithms.

Communication Links. The Blue force was assumed to have full communication link. As for the Red force, it was assumed that the individual boats were operating in accordance to mission plans without any communication links.

KEY MODELING PARAMETERS

Blue Forces. The Blue forces consisted of three KINs and three patrol vessels (PVs). The following modeling parameters were assumed.

- KINs Self-protection. Each KINs were assumed to have a detection range of 5 nm and protected by General Purpose Machine Guns (GPMGs) with the following specifications.

CSR Detection Range (nm)	5
Weapon Range (km)	2
Weapon Single Shot Probability of Hit (SSHP)	0.1

Table 1: Specifications of KINs Self-protection

- Patrol Vessels. Each PVs was assumed to conduct normal patrol at 15 knots and give chase at a maximum speed of 25 knots. The PVs were also assumed to be capable of neutralizing the Red boats by closing in within 0.5 nm and maintaining this distance for 1 min. The dynamics of the close water combat was not modeled. In addition, the PVs would be activated to investigate detections made by the CSRs so as to achieve target identification and neutralization. A summary of the key specifications of the Blue PVs was as follows:

PV Speed [Patrol] (knots)	15
PV Speed [Chase] (knots)	25
PV Detection Range (nm)	3
PV Identification (ID) Range (nm)	1

Table 2: Specifications of Blue PVs

Red Forces. Five Red boats were modeled as small fishing boats with a maximum speed of 25 knots and loaded with explosives. These boats were assumed to be without any onboard sensors and have a visual detection and identification range of 1 nm.

Maximum Speed (knots)	25
Detection/ID Range (nm)	1

Table 3: Specifications of Red Boats

MEASURE OF EFFECTIVENESS

The MOEs were:

- Number of Successful Red attacks on KINs/ Coastline
- Red Attrition

METHODOLOGY

Refinement of Blue Plan

The team members were asked to refine the Blue patrol plan as the baseline scenario may not be adequate to present a strong case for surprises to develop during the MRT and ART phase. After several rounds of deliberations and trials, the team decided on deploying a Blue standby PV (goalkeeper) in the vicinity of one of the KINs while the other two PVs were deployed as forward patrol within the detection range of the KINs. A broad deployment concept for the improved Blue patrol plan is as shown in Figure 2 below.

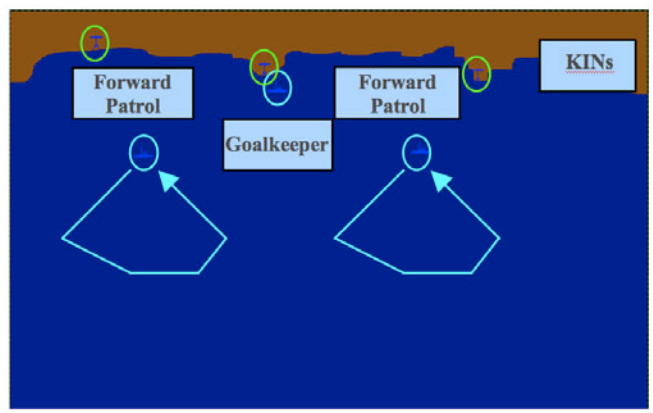

Figure 2: Refined Blue Patrol Plan

Manual Red Teaming

After the Blue patrol plan had been refined, the team then went on to develop the Red attack plan through MRT effort. Two Red plans were developed as a results based on different tactics and deployment concept.

Flanking Tactics. Firstly, the team noted that the Blue forces were concentrated in the middle and decided to deploy the Red forces into two different groups to approach the targets on the flanks. A schematic of the deployment plan is as presented in Figure 3 below.

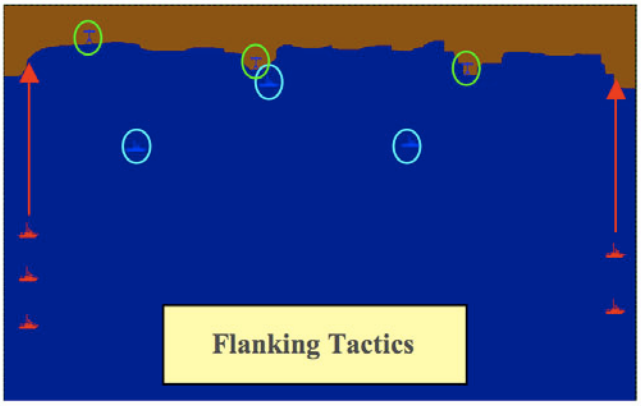

Figure 3: Flanking Tactics

Decoy Tactics. Next, the team then went on to develop the second Red tactic that was as effective as the first one (achieve 100% Red mission success) but not exactly as efficient (higher Red attrition). The second concept involved a group of three Red boats approaching from a central route to provide decoy for the other two Red boats on the sides to dash for the targets. A diagram on the deployment plan is as shown below in Figure 4.

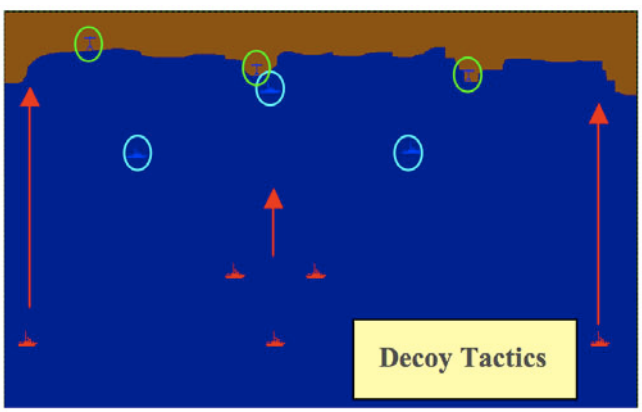

Figure 4: Decoy Tactics

Automated Red Teaming

Formulation of Red Tactics through ART. Subsequently the team used the ART framework to develop two Red tactics[2] (ART Tactic 1 and ART Tactic 2) for comparison against the MRT efforts, through the evolution of the following parameters.

- Individual Red Boat Starting Positions
- Individual Way-point Positions
- Aggressiveness (Propensity towards Enemy)
- Cohesiveness (Propensity towards Uninjured Friends)
- Determination (Propensity towards Waypoint)

Decoy and Flanking Tactics complemented with ART. Both the Decoy tactic and Flanking tactic developed through MRT effort were further red-teamed through the ART framework by evolving the following intangibles parameters:

- Aggressiveness
- Cohesiveness
- Determination

RESULTS AND ANALYSIS

ART Tactics 1

Concept of Decoy. It was interesting to note that the ART framework produced a surprising variation of decoy concepts. Under the plan, one of the Red boats from left was deployed to draw the Blue PV on the left towards the right side to create an opening for the other two Red boats to charge towards their objectives. This deployment was counter-intuitive as most of the team members had initially written it off, thinking that longer exposure would lead to lower survivability and hence lower mission success.

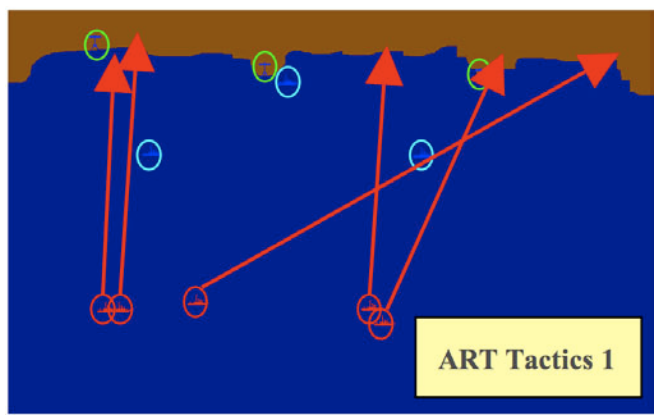

Figure 5: ART Tactics 1

ART Tactics 2

Saturation Tactic. In ART tactics 2, a mix of saturation and decoy deployment concepts were applied to achieve the optimal tactic. Nonetheless, it is apparent that saturation contributed more to the Red mission success. The group of four Red boats on the left was

2 ART Tactic 1 was developed during IDFW 14 while ART Tactic 2 was a post-workshop run for robustness of results.

deployed to saturate the Blue forces. The eventual engagements would then allow those remaining Red survivals to slip through and achieve mission objectives, as shown in Figure 6 below.

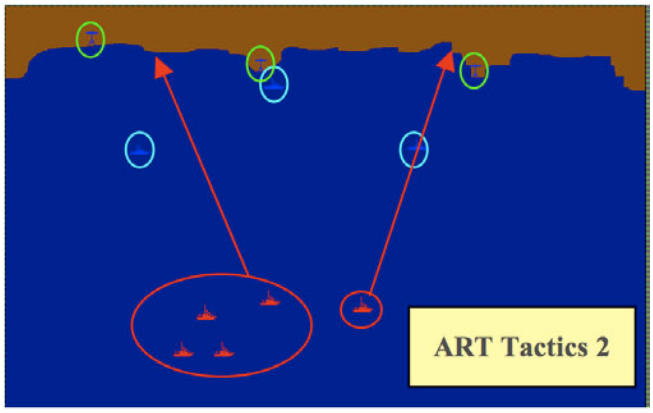

Figure 6: ART Tactics 2

MRT complemented with ART

From the results below in Table 4, it was evident that there was marked improvement in the Red mission success and Red attrition after evolving the intangibles using the ART framework. All the plans through the MRT and ART efforts produced a 100% red mission success but shown varied levels of improvement for the Red attrition. The best plan was the flanking tactics which produced an improvement of 86.7% to a mere 0.41 Red attrition.

	Base	Flanking		Decoy		ART Tactics 1	ART Tactics 2
		Orig.	ART	Orig.	ART		
Aggressiveness	-60	-60	-76	-60	-30	-83	-74
Cohesiveness	-100	-100	16	-100	60	8	26
Determination	60	60	86	60	73	53	80
Red Mission Success	47%	100%	100%	100%	100%	100%	100%
Red Attrition	2.51	0.85	0.41	3.05	1.69	1.89	0.95
% Improvement (Red Mission Success)	N.A.	113%	113%	113%	113%	113%	113%
% Improvement (Red Attrition)	N.A.	66.1%	86.7%	21.5%	32.7%	24.7%	62.2%

Table 4: ART Run Results

SUMMARY OF FINDINGS

Through the exercise during IDFW 14, two broad observations were made.

MRT complemented with ART. Firstly, the team managed to show that through the evolution of intangible parameters, ART was able to enhance the Red performance from their MRT tactics. Therefore it reinforced the belief that MRT efforts can be further enhanced using the ART framework.

Surprises from ART. Secondly, it was interesting to note that the ART had produced plans that has in-cooperated similar decoy tactics, as in the manual decoy tactics, and offered an alternative approach that has been written off initially.

CONCLUSIONS

This study has discussed some of the strengths and weaknesses of the ART framework. Despite its limitations, ART framework had proven its worth and is highly recommended to be used to complement MRT efforts during the ops planning phase.

LOOKING AHEAD

The next phase for the ART project is to embark on the Automated Co-Evolution (ACE). ACE will be looking at Blue Teaming vs Red Teaming in typical 2-sided scenarios, using evolutionary algorithms.

Team 8: Representing Situation Awareness in Agent Based Models

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GOALS

The ultimate aim of the Combat Identification (Combat ID) team is to enable the representation of Combat ID characteristics and behavior within a constructive simulation in order to enable the exploration of the benefit of system interventions based on Situational Awareness, Target Identification, Human Factors and TTPs in terms of increasing combat effectiveness and reducing fratricide levels. The main goal of our team for IDFW14 was to assess the feasibility of a representation of Situation Awareness (SA) and Target Identification (TI) in an Agent Based Model (ABM).

EXPERIMENTAL DESIGN

The Net Logo tool was selected for the representation of the SA agents and used to develop an experiment with a deliberately simple overall design.

- A battlespace is populated with red (enemy), green (neutral) and blue (friendly) entities.
- The battlespace is characterized by a preconception grid representing the decision making agent's (DMA's) belief of the allegiance of any entities present within a particular grid square.
- The DMA is randomly positioned and moves randomly around the grid, detecting entities, then approaching them to make classification and identification decisions.
- This process continues until either 5000 timesteps have passed, or all entities have been identified.

The experimental design derived 16 datafarmable variables which were used to populate a Nearly Orthogonal Latin Hypercube. The following outputs were selected to be recorded within the output data file:

- Number of identifications
- Percentage of entities identified
- Number of correct identifications
- Average Range at identification
- Number of incorrect identifications
- Average Confidence at identification

Results

Unfortunately development of the tool was not completed in time to undertake any analysis. However, the development process showed that the representations are feasible, and that future refinement of the process is likely to replicate the required behavior. It is intended to continue to develop the model with a view to using it to undertake analysis at a future workshop.

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Team 9:
Healthcare Applications of Data Farming

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INTRODUCTION

Healthcare in the United States is expensive and inefficient. As a whole, it is at least ten years behind other industries in the application of information technology to processes and practices. Hospital administrators, with a cadre of consultants and vendors in tow, are rushing to catch up, spending billions on IT. Unfortunately, process knowledge is often lacking, and technology interventions fail to achieve their goals. This contributes to the low rate of adoption—less than 10 percent—of tools such as electronic medical records.

Healthcare is a complex adaptive system with multiple independent and interdependent agents. It is not easily understood, and experiments are difficult to conduct without putting patients at risk. Data farming offers the opportunity to explore the interactions of multiple variables and interventions. As a first step in examining the value of data farming to healthcare, the team set out to model the charting process in medical/surgical units. A chart is the medical record of a patient during their stay in the hospital. It is the history of their observations, tests, medications, diagnoses and procedures. Despite the availability of robust digital technology and infrastructure, this remains largely a paper-based process.

Process and Preliminary Results

The paper-based charting process was mapped using the input of two subject matter experts and one researcher. In addition to identifying the steps in the process, the range of time required and the resources used were noted. The process followed the patient from admission to discharge, focusing on how information was collected, recorded and communicated. A second process map was generated for a digital system. This system assumed the existence of a variety of computer portals for recording and accessing medical information. Portals were *fixed* (e.g., nurse stations, offices), *mobile* (e.g., carts) and *personal*, handheld devices (e.g., PDA's, cell phones).

Both processes were modeled using Arena software. To successfully complete the task, a number of assumptions were made regarding the range and distribution of time required to complete various activities. Both models were completed, but the results were erratic, implying that some of the team's assumptions were in error. More accurate data are needed to improve the value and reliability of the model. Nonetheless, the analyses suggested that significant time could be saved during admission and discharge with a digital system.

Next Steps

Four tasks were identified to improve the model. First, additional resources will be sought to increase accuracy. This includes published research, observational studies currently underway at the University of Memphis, and additional subject matter experts. With this information, the second task will be to improve the Arena model. A third task is to replicate the model using NetLogo. This will enable the team to simulate agent behavior as well as processes. The final task is to reconvene—and expand—the team in a meeting at the University of Memphis later this spring. As the model becomes more sophisticated, it will be used to explore the impacts of various human resource, technological and architectural interventions.

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Team 10: Comparison of Ground-based Fire Support Capabilities of the Marine Expeditionary Unit

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Problem Statement:

The team objective was to compare the ground-based fire support capabilities of the Marine Expeditionary Unit (MEU) in order to gain insights that are relevant to organizing the MEU for operations. Specifically, two systems, the Expeditionary Fire Support System (EFSS) and the 155mm lightweight howitzer (M777), were the focus of the analytic effort. The scenario for the comparison employed Ship-To-Objective Maneuver (STOM) tactics and USMC Expeditionary Maneuver Warfare doctrine.

Method:

Utilizing the Map Aware Non-uniform Automata (MANA) agent-based simulation, the objective was to compare the EFSS and M777 using prescribed measures of effectiveness. Within this context, the team explored the following during IDFW-14:

- Is one system clearly dominant?
- Explore the effects of different quantities and capabilities of systems.
- Determine what system and ammunition configurations are robust.
- ID additional factors or scenarios that demand attention.
- Run a prototype DOE for initial findings and verifications?

Within the scenario, the group chose not to model Blue Force (BLUFOR) or Red Force (REDFOR) radar target acquisition capabilities nor did it assign any artillery units specific counter-battery fire missions. To emulate the effects of the organic MEU Air Interdiction (AI) capability, REDFOR interdiction by a Joint Strike Fighter package was programmed in as an initial condition. As such, REDFOR ADA assets are not in the model.

Analysis:

The modeling in MANA allowed the team to account for specific physical characteristics of each artillery system. This facilitated data collection that was specific to initial conditions in a randomized multi-factor experimental design (DOE).

To compare the artillery systems, the team used four measures, ammunition (CLV), mobility, range, and probability of kill(Pk). Ammunition represents initial CLV supply based on Unit Basic Load (UBL) allotments. In addition, it addresses the type of ammunition breakdown per system, (DPICM, PERM, HE, and RAP).

The scenario, a static defense, did not offer great opportunity to examine tactical mobility and no operational mobility. Firing batteries only moved when fired upon for survivability. M777 units did not have this capability organic thus never moved.

Range accounts for system and ammunition capabilities. In general, the M777 has an overwhelming advantage, as is the case with Pk. Pk is a function of ammunition lethality in terms of kinetic energy and precision.

The group identified the following factors in the experimental design.

* Contact information: dalovela@nps.edu

a. Initial # of EFSS Tubes
b. Initial # of M777 Tubes
c. RAP - M777
d. DPICM – M777
e. HE – M777
f. PERM - EFSS
g. HE - EFSS
h. UAV Presence
i. EFSS "shot at" trigger state (mobility)
j. Unit Basic Load (UBL), Vary by +- 50%
k. Attrition of Red Forces by CAS/AI for initial condition

A small scale experiment was run using the first nine factors. Applying a design using the nearly-orthogonal Latin hypercube for 23-29 factors, there were 257 design points.

There were 5 statistics of interest for each run, number of total red casualties, number of total blue casualties, $\frac{blue\_casualties}{red\_casualties}$, and $\frac{red\_casualties}{blue\_arty\_round\_fired}$ for EFSS, and $\frac{red\_casualties}{blue\_arty\_round\_fired}$ for M777. Only the first 3 were captured for the small scale experiment.

Initial Findings:

M777 is dominant in a static defense. Any configuration that does not maximize M777 systems is not optimal. If only EFSS is employed, mobility is the dominant factor, then PERM.

The Way Ahead:

Scope of comparison should increase to include a variety of BLUFOR operations. There may be situations where is it favorable to employ EFSS. In addition, future simulations should include activities to represent operational mobility tasks, tactical mobility tasks, and CLV supply and resupply tasks.

Team 11: Future Force Warrior Experimentation and Analysis

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Summary

The U.S. Army is undertaking its most significant transformation in decades. Leveraging new technologies, the evolving Future Force is characterized by a lighter, more agile, soldier centric force. The military operations research community is working on ways to better analyze soldier capabilities and systems of systems. This team will explore the use of IWARS in a high performance computing environment, building on previous and ongoing work done at TRAC-MTYRY and NPS. The team will build appropriate squad and platoon level scenarios and designs of experiments to examine a variety of issues of interest to the FFW program. The results of this analysis will impact ongoing testing during the current fiscal year.

Model Representations

- Pythagoras.
  - Government owned ABM.
  - Populated with unclassified AMSAA data.
  - SME input into behavior development.
- IWARS.
  - High resolution entity level model.

- Scenario.
  - Movement to contact in an urban area with mission to enter and clear a building.
  - McKenna MOUT site.
- Friendly Forces.
  - FFW SCU (squad in IWARS) operating as part of a larger unit with FCS enablers.
  - External fires limited to 60mm mortar.
- Threat.
  - 2-4 man teams equipped with AK47s, RPKs, limited UAV access, and limited night vision.
  - Threat wears civilian clothes in Pythagoras.

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Team 12: Joint Dynamic Allocation of Fires and Sensors: Experimental Interface and Analysis

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INTRODUCTION

The Joint Dynamic Allocation of Fires and Sensors (JDAFS) simulation is a publicly available discrete event simulation that accounts for first order combat effects using Army approved algorithms. It couples dynamic allocation of resources such as unmanned platforms and artillery assets using optimization to a simulation to render better representations of network enabled warfare. The current configuration is not user friendly when entering the DOE factors. This is problematic for a number of reasons. First, the potential for data entry errors is significant when entering a large volume of numbers. Second, the data entry is not only time consuming but potentially expensive. Finally, an operator/analyst needs to be present as the runs are completed in order to start the next design point evolution. The potential for errors and the inherent inefficiencies warrant the development of a method to easily run a DOE if JDAFS is to be more widely used.

JDAFS

The first team goal was to refine and test a Joint Intelligence, Surveillance, and Reconnaissance trade-off analysis scenario in JDAFS. As an initial test of functionality, the most complex ISR scenario loaded and ran. The first optimization interval took over an hour to build before the scenario could begin. The team decided to implement a much simpler scenario (240 hours) which ran to completion in a matter of minutes. A number of output and execution issues were initially noted and corrected in the latest software build. The workshop was valuable for revealing scenario, data entry, and program anomalies for correction prior to the pending production runs.

The purpose of this research is to use the JDAFS model to simulate the effects of varying key factors associated with the operation and employment of manned and unmanned ISR platforms. An analysis of the trade-offs associated with specific platforms and basing decisions on the execution of penetrating vs. non-penetrating missions will be the outcome and main focus of this research. The analytical findings will provide a foundation for decisions regarding ISR.

Design of Experiments

A Design-of-Experiments (DOE) will be developed based on scenarios and data provided in order to execute the Joint Dynamic Allocation of Fires and Sensors (JDAFS) simulation model. In establishing the DOE, specific factors will be identified that determine the key attributes of timely, survivable, and persistent. Once the factors have been identified, the range of levels to be taken on for the various factors will be set for examination with in the DOE framework. Due to the number of factors involved, a full-factorial design, examining every possible combination of inputs would be impractical. Therefore, an efficient, robust DOE will be employed to examine the response surface. Output from the simulation runs will be analyzed to evaluate how the various input factors affect the predetermined Measures-of-Effectiveness (MOE) across the range of scenarios.

The platforms and key performance parameter used are shown in Table 1.

PLATFORM	MAX ALTITUDE (meters)	SPEED (meters/ hour)	ENDURANCE (hours)	TRANSITION TIME (hours)
RQ-1	7925	148160	24	1.5
RQ-4	18288	629860	24	1.5
P-3	8839	422256	12	1.5
RC-135	10668	805629	11	1.5
U-2	21336	824140	10	1.5

Table 1 - ISR Platform Performance Parameters

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Each platform had varying sensor capabilities depicted in Table 2.

PLATFORM	SENSOR	RANGE (meters)
P-3	EO/IR	75000
P-3	SAR	200000
RC-135	ELINT	300000
RQ-1	EO/IR	50000
RQ-1	SAR	200000
RQ-4	EO/IR	300000
RQ-4	SAR	75000
RQ-4	ELINT	200000
U-2	EO/IR	400000
U-2	SAR	100000
U-2	ELINT	250000

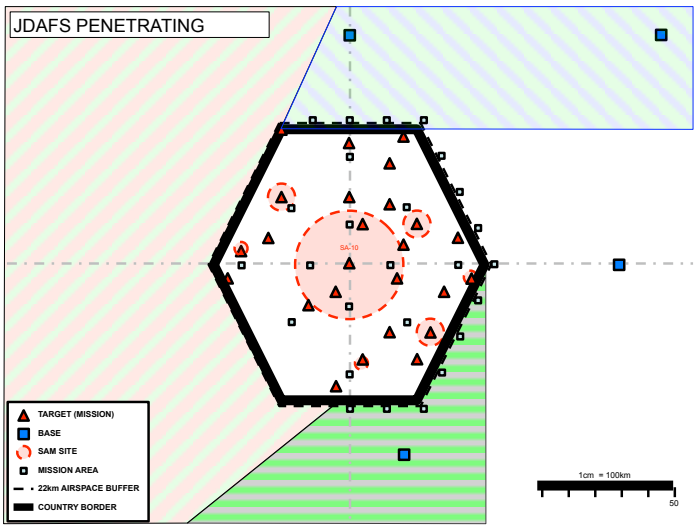
Table 2 - ISR Platform Sensor Ranges

Scenarios

Two types of scenarios were generated for examination and comparison with JDAFS. The first scenario is a non-penetrating scenario (See Figure 1) where the ISR platforms do not penetrate the Country of Interest's national airspace.

The internationally accepted buffer of 22 kilometers is respected on all flights and waypoints have been implemented to prevent ingressing and egressing aircraft from violating the COI's sovereign airspace. The second scenario (See Figure 2) assumes that conditions have changed to allow the violation of the COI's airspace. With the incursions into the COI's territory comes the risk of engagement by air defense assets, in this case surface-to-air missiles (SAM).

For the purposes of this simulation 25 missions or targets of varying types were created and populated through out the COI. Target types consisted of command and control (C2), surface-to-air missiles (SAM), short range ballistic missiles (SRBM), medium range ballistic missiles (MRBM), long range ballistic missiles (LRBM), airfields, weapons of mass destruction facilities (WMD FAC), military facilities (MIL FAC), and ammunition storage (AMMO STOR) facilities. Each type of target can be collected against by specific types of sensors. The mission/sensor interactions must be explicitly created in the input tables and result in the actual creation of 76 target elements from the 25 actual missions (targets).



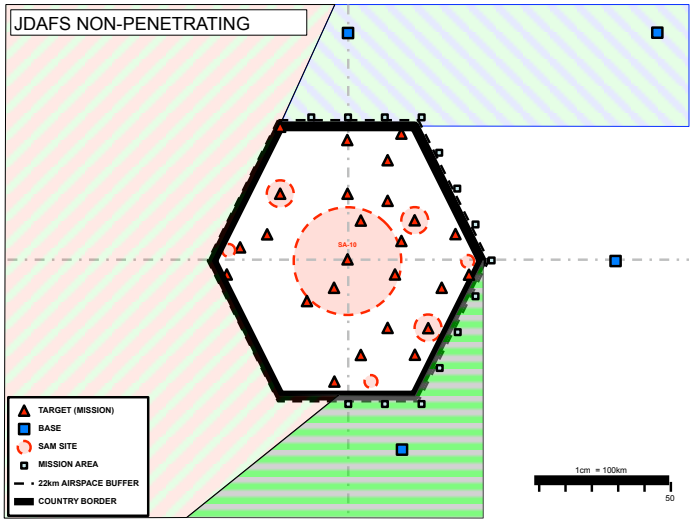


Figure 1. JDAFS Non-penetrating Scenario

Data Farming Interface

The second team goal was to develop a data farming interface (or at least requirements for one) that lends itself to analyst ease of use. A number of interesting design considerations for the design of experiment tool arose during conference discussions within the working group and with members of other teams. These discussions included whether or not a baseline scenario should be required; including a set of parameters with their types and descriptions as candidate DOE factors as a part of any DOE tool; guiding a user and allowing robust design

selection; design point generation; and experiment distribution practices to a computing cluster.

MISSION	TYPE	EO	SAR	ELINT
1	C2			X
2	SA-2	X	X	X
3	WMD FAC	X	X	
4	IRBM	X	X	X
5	AIRFIELD	X	X	X
6	SRBM	X	X	X
7	C2			X
8	C2	X	X	X
9	SA-2	X	X	X
10	SA-2	X	X	X
11	C2			X
12	AMMO STOR	X	X	
13	AMMO STOR	X	X	
14	IRBM	X	X	X
15	LRBM	X	X	X
16	SRBM	X	X	X
17	MIL FAC	X	X	
18	WMD FAC	X	X	
19	MIL FAC	X	X	
20	MIL FAC	X	X	
21	IRBM	X	X	X
22	MIL FAC	X	X	
23	C2			X
24	AIRFIELD	X	X	X
25	SA-10	X	X	X

Table 3 - Targets and Required Sensors for Collection

For JDAFS, a method was developed so that the analyst can specify which input factors are to be varied, match those factors with a design, and generate the corresponding input database. For each design point, the DesignGenerator program uses SQL statements to create a corresponding input file. JDAFS writes its output reports to the same database that was used for input, so there is always a direct association between input and output values.

Execution of JDAFS is oriented towards a single run with a single input file; there is no built-in capability in JDAFS itself to run experimental designs. Yet executing JDAFS with various input factors set based on efficient designs is essential to its effective use. It is also critical to being able to use JDAFS for data farming. The normal input to a JDAFS scenario is currently via an Access database; in the near-term, support for other databases such as MySQL, Oracle, and Derby will be added.

A method was developed so that the analyst can specify which input factors are to be varied, match those factors with a design, and generate the corresponding input database. This was done so that there was no impact whatsoever on the basic input database, and so that the specific experimental design used was completely swappable. That is, the analyst could keep the same basic input scenario and same set of factors, but swap in any experimental design scheme that was desired with only a minimal amount of changes.

Given a database input format and instance (scenario), any possible data element in the database is a potential design factor. Practically speaking, however, for a model such as JDAFS, large groups of data elements together can constitute a single factor. For example, the maximum range for a particular type of sensor is one possible factor. Setting that factor requires more than changing a single value; all "max_range" columns corresponding to that sensor must be changed to correctly set the factor to its correct level.

To have a concrete use-case, we chose the nearly-orthogonal Latin hypercube design implemented by the spreadsheet by Susan Sanchez (Sanchez, 2007, http://harvest.nps.edu/LinkedFiles/NOLHdesigns_v4.xls). For simplicity, the only types of factors initially considered were continuous and integer. The values from the spreadsheet for each set of factors were normalized to a range of [0, 1] and saved in plain-text comma-separated (csv) files. Conceptually, these files constitute tables in a virtual database (and future versions will be implemented as such); therefore, we represent these tables of values as a database called "Designs." Different schemes can be used to generate these tables of values without modifying any other part of the input or the code.

The Factors database consists of two tables: one to identify factors in the template database by table and column, together with a user-specified minimum and maximum value, and a second table that maps the number of factors (determined by the number of rows in the first table) to one of the design point files. That table is then read, and the corresponding values

applied to the minimum and maximum values to produce an input value. The "DesignGenerator" program that does this is written in Java and uses Java Database Connectivity (JDBC) to access the databases. Hence, using different databases will only require that a different JDBC driver be installed.

For each design point, the DesignGenerator program uses SQL statements to create a corresponding input file, which is numbered <name>xxxx.mdb, where "xxxx" is an index corresponding to the particular design point index. All the input from the template database is copied, and those entries that are factors are modified using the SQL UPDATE query to be set to the design point values. An additional table is written that identifies the particular names and values of the input factors. This information will be used after JDAFS is executed to extract the independent and dependent variables for statistical analysis.

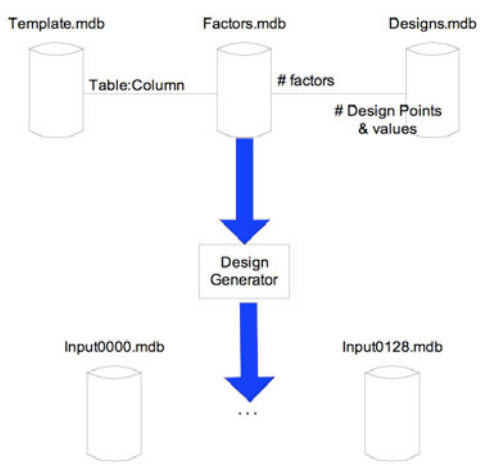


Figure 3. DesignGenerator Producing Input Files

JDAFS can write its output reports to the same database that was used for input, so there is always a direct association between input and output values.

The next step is to take the set of databases containing input and output and process them to produce a file or database suitable for statistical analysis; that is, in a suitable input format for a statistical package such as JMP. This will essentially be the reverse of the flow in Figure 3.

RESULTS

The JDAFS simulation provides for the generation of a number of Measures of Effectiveness including, Coverage, Coverage by Type, and Attrition. Sensor coverage is the focus for this analysis. An initial plot of the distribution and summary statistics for 274 design points in the non-penetrating scenario is shown in Figure 4. The coverage results appear to be roughly normally distributed with a mean of 0.48. The five outlying data points at the bottom of the outlier box plot warrant further examination.

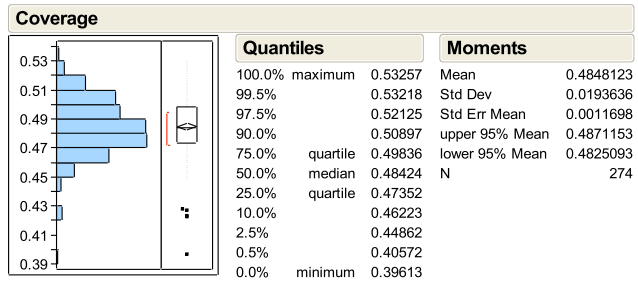


Figure 4. Distribution and Summary Statistics of Mission Area Coverage

An examination of the data reveals that four of the outlying data points 1, 2, 4, and 265 are the result of design points having only a single base available for operations. Even though each operating location had a full compliment of aircraft (21 total airframes), the mean coverage ranked at the bottom of all the results. When ranked from greatest to least coverage, D, C, A, then B, this ordering is not surprising when compared to the mean distance of the bases to their mission areas in the pre-simulation analysis. Having a single operating base available to ISR platforms in a region of the size encompassed in this study is unrealistic. Therefore, the design points that include only one operating location will not be considered for the remainer of this analysis.

For comparison with future models, a full quadratic model with the outlying data points was constructed. Figure 5 shows this model. Note that the R-squared value for this model is 0.73.

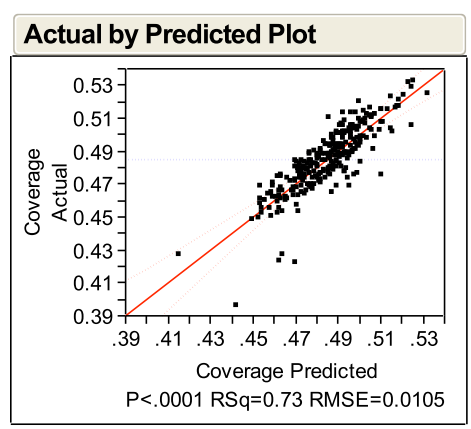


Figure 5. Actual by Predicted Coverage Plot for Full Quadratic Model with Single base Outliers included.

After removing the single base outliers, the distribution and summary statistics for the non-penetrating scenario data were recalculated. The increase in the mean coverage is negligible but the remaining data more closely approximates a normal distribution.

From the final 270 design point dataset a full quadratic model with main effect, interaction, and polynomial terms was created. The Stepwise Regression Control settings within JMP were as follows:

- Probability to enter: 0.01
- Probability to leave: 0.01
- Direction: Mixed

The Construct Model Effects macros for Factorial to Degree and Polynomial to Degree were set at 2 to add two-way interaction and quadratic terms.

The resultant model achieves an R-squared of 0.78 and contains 12 main effect terms, 4 interaction terms, and 3 second order terms. See Figures 6 and 7 for the regression plot and a list of the regression model terms.

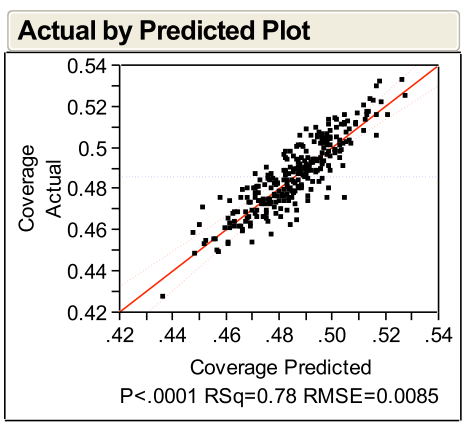


Figure 6. Actual by Predicted Coverage Plot for Full Quadratic Model with Single Base Outliers Removed

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.4762323	0.002843	167.51	<.0001*
A RQ-4	-0.002767	0.000534	-5.18	<.0001*
A RQ-1	-0.000885	0.000285	-3.10	0.0021*
A RC-135	0.0039884	0.000535	7.45	<.0001*
A U-2	0.0056309	0.000536	10.50	<.0001*
B RQ-4	-0.002767	0.000541	-5.12	<.0001*
B RC-135	-0.000835	0.000538	-1.55	0.1219
B U-2	0.0035851	0.000534	6.71	<.0001*
C RQ-4	-0.002511	0.000531	-4.73	<.0001*
C U-2	0.0058404	0.000531	10.99	<.0001*
D RQ-4	-0.001957	0.000529	-3.70	0.0003*
D U-2	0.0074843	0.000532	14.07	<.0001*
OPT INT	-0.004388	0.000361	-12.15	<.0001*
(A RQ-4-1.52963)*(B RC-135-1.52963)	-0.002434	0.000522	-4.66	<.0001*
(A RC-135-1.52963)*(D RQ-4-1.52963)	-0.001769	0.000518	-3.41	0.0007*
(B RC-135-1.52963)*(D RQ-4-1.52963)	-0.001793	0.000535	-3.35	0.0009*
(C RQ-4-1.52963)*(D U-2-1.52963)	-0.002549	0.000504	-5.05	<.0001*
(B RQ-4-1.52963)*(B RQ-4-1.52963)	0.001986	0.000574	3.46	0.0006*
(C U-2-1.52963)*(C U-2-1.52963)	-0.001624	0.00057	-2.85	0.0047*
(D RQ-4-1.52963)*(D RQ-4-1.52963)	0.0030399	0.000559	5.44	<.0001*

Figure 7. Full Quadratic Coverage Model Terms

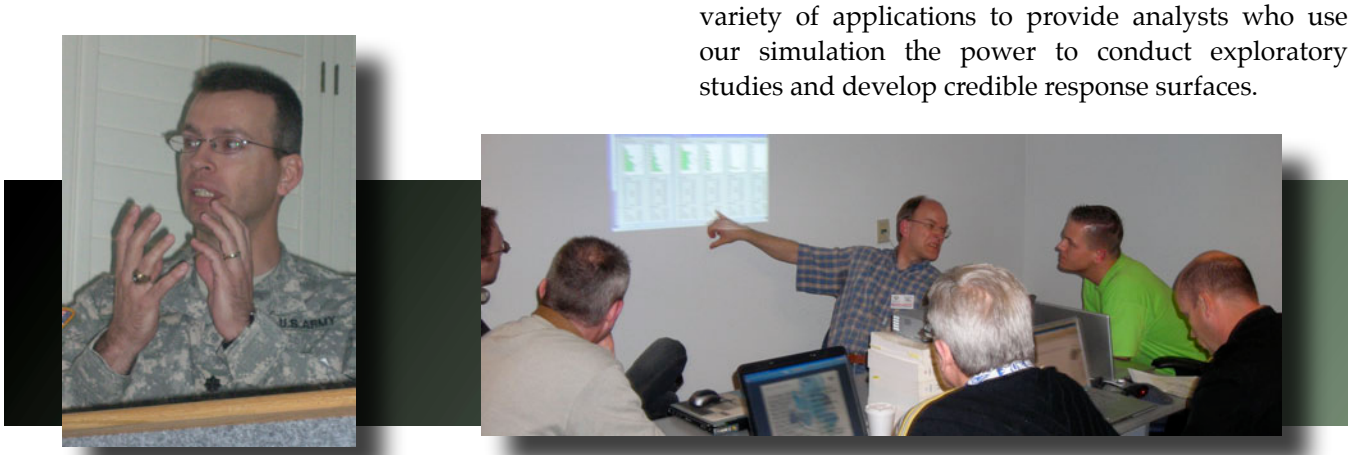
As expected, the most capable platforms, the U-2 and RQ-4, show up as terms from each base. The RC-135 is reflected twice from Bases A and B. The RQ-1 from Base A is the only entry for that platform. Interestingly, the P-3 is not represented in the model at all. In addition to the aircraft factors, the optimization term is also included in the final model.

To test the validity of the Coverage Full Quadratic Regression model the regression assumptions were verified.

CONCLUSIONS

A scenario was developed, largely within JDAFS, that credibly represented the effects of joint sensors and was able to measure the trade-offs of varying platforms using JDAFS network-enabled assignment optimization.

A data farming interface was developed that began the process of enabling the power of JDAFS. In the coming months, this interface will be refined for JDAFS but, more importantly, generalized for a wide variety of applications to provide analysts who use our simulation the power to conduct exploratory studies and develop credible response surfaces.



Team 13: Modelling Technical Aspects of NCO (Convoy Protection)

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INTRODUCTION

The German Federal Office of Defense Technology and Procurement has been analyzing the influence of networked sensors and effectors on military capabilities. The background of our overall scenario is peace support operations (PSO) in an urban environment. The background for the actual technical evaluations of sensors, effectors and the connecting network is the following scenario vignette: Convoy Protection.

The forces at a sanctuary in the center of a city are supplied with fuel, ammunition and food transported by a convoy running from the headquarters, located at the airport. This convoy is protected by:

- Two check points as flank protections
- UAV, UGV
- AWC (Wiesel)
- LIV (Fuchs)

Evaluation of the Ground Picture: The convoy leader is connected to the mission cell at his headquarters and as well to the leaders of the check point. He can react on information received from the UAV and UGV on possible trafficability of the pre planned route. Detours are possible.

There is an asymmetric threat: A local burning obstacle brings the convoy to a stop. Mobile barriers in an ambush, snipers and bazooka shots are looking for an opportunity to intercept the convoy.

The MOE's are:

- the delivery time and
- BLUE casualties.

The technical effects of special sensors and effectors at the convoy and his NCO capability will be examined. The basic implementation of the scenario in MANA was the task during PAIW 12. The challenge of modelling was the level of detail.

The simulation tool in IDFW 14 will be MANA, again, in spite of our realization of the limitation of the tool MANA in this scenario. The experiment design will follow the NOLH design and possibly a mixed NOLH/Grided Design. The idea is to follow a three step approach:

- Step 1: using existing equipment (sensors, effectors)
- Step 2: using equipment under development (sensors, effectors)
- Step 3: using future equipment (sensors, effectors).

Variations will be investigated in the technical representation of UAV / UGV speeds, communication and sensors, in scenario details and in a variation of protection and equipment.

For the planned investigations three scenarios were prepared. Two of them differ in the distance between the vehicles. In one we took 50 meters and in the other we took 10 meters (which is more usual for the German Bundeswehr). These two scenarios have to

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be assigned to the mentioned Step 2 because a UGV or a UAV are not introduced to the forces yet.

The third scenario belongs to Step 1. Here we replaced the reconnaissance-devices by just the human eye. A vehicle of the escort drives up to the junction, checks the surrounding area and triggers the convoy depending on the observed.

Step 3 was partly covered by a corresponding choice of the intervals for the parameters in the DoE. Modifications of the scenarios due to step 3 could not be made because of the shortness of the workshop.

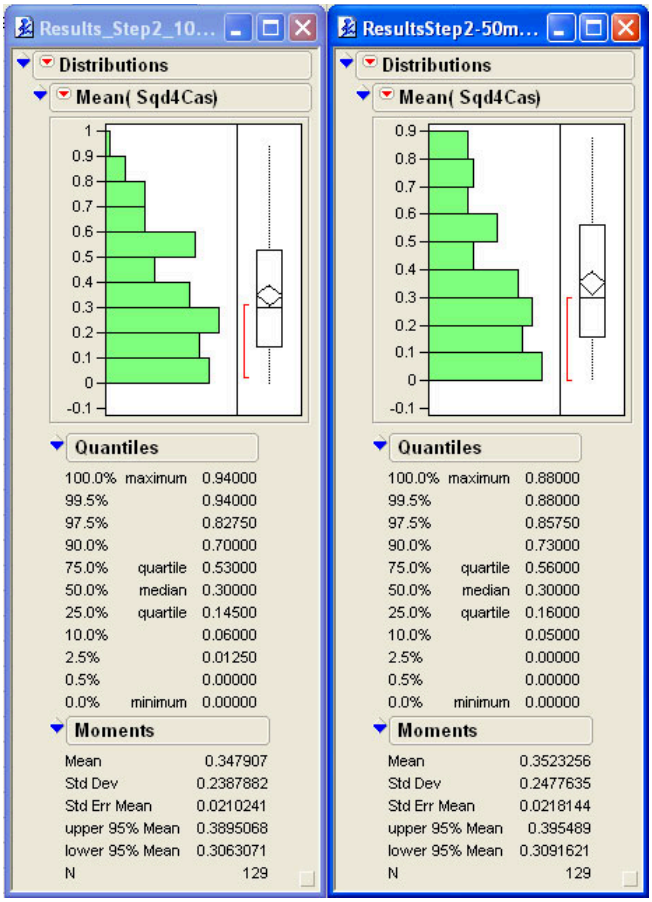

Figure 1

The first series of experiments was made in vain. We started with the DoE which we already used for IDFW13 in Scheveningen. There we intended to investigate the most important parameters of the sensors, the convoy, the network and the irregular forces. We extended that design by the "concealment" attribute of the terrain, the "stealth factor" of the irregular forces and the "number of hits to kill" of the supply vehicles. The "concealment" attribute is an element of the unit interval [0,1]. OldMcData and/or the Tiller could not handle these values and rounded them to zero. So the experiments were conducted without concealment. That wasn't our intention.

From the next series of experiments we learned the different distances between the convoy's vehicles don't have a significant influence on the MoE. You can observe this outcome for example in the following picture (Figure 1) where the distributions of the casualties of the first supply vehicle are compared.

On the left-hand side we see the corresponding distribution of the 10m – scenario and on the right-hand side the one of the 50m-scenario. They are almost the same. The mean and the other empirical values are almost the same. Therefore we decided not to consider the 50m – scenario in the following experiments.

The tactics of the irregular forces were modeled the following way. They shoot at the vehicles when they see fit. The next picture (Figure 2) shows the street with the ambushing red forces. The two soldiers at the lower and the upper end of the street are the bazooka shots. It is obvious that the modeled tactic is not an efficient tactic. Therefore we changed it. For the next experiments the red forces stay covered until the bazooka shot at the upper end of the street opens fire by shooting at the leading vehicle. Then the others will shoot when they see fit.

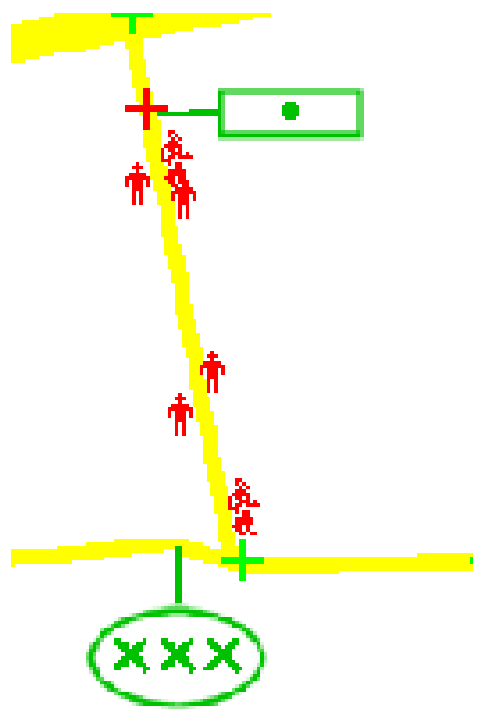

Figure 2

With the next pictures we will see the differences in the outcome of the experiments with the Step2-

scenario. The following picture (Figure 3) shows the distributions of the casualties of the four supply vehicles with the old tactic of the red forces.

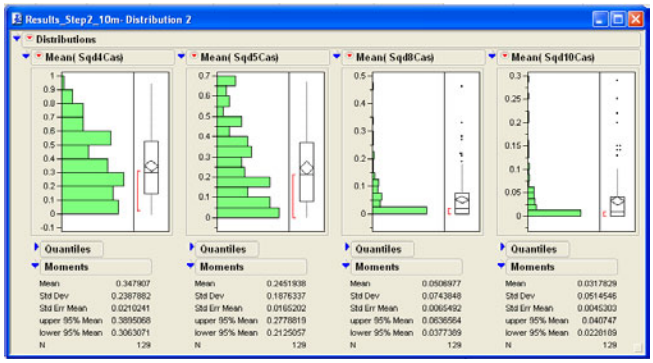

Figure 3

The next picture (Figure 4) will show us the consequence of the new tactics.

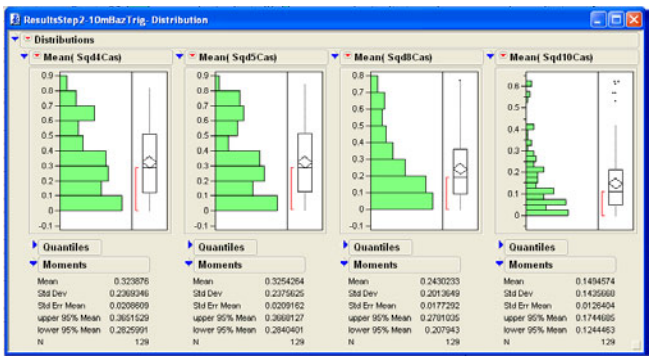

Figure 4

Especially the two distributions on each right-hand side are very different. The mean of the casualties of the first tanker rises from 5 % to 24 %!

Finally we will have a short look at the comparison between Step 1 and Step 2. The results as far as the fight is concerned will not be different because there are no differences in the modeling. The only difference that can be expected is the performance of the reconnaissance.

The picture (Figure 5) shows the distributions of the casualties of the indicator agent for the original route. The means are the probabilities of detection. On the left side we see Step 1 with the probability of detection of 2%. On the right side the probability is 31 %. That means quite an improvement.

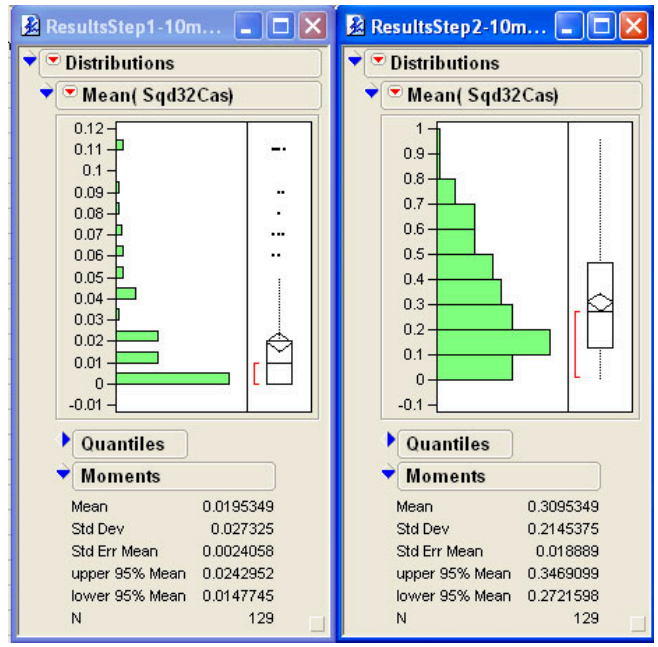

Figure 5

Unfortunately it was not worth to go into deeper comparisons. We observed in the results that the scenarios especially the one of Step 2 didn't work correctly. Almost one third of the results were wrong. We saw it by comparing the casualties of the leading vehicle and the number of arrivals at the mosque.

PAX: Designed for Peace Support Operations

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Modeling Peace Support Operations

Peace support operations represent a new challenge. The forces have to master a multitude of difficult-to-calculate, asymmetric threats. In recent missions, the soldiers must manage completely new problems which have little in common with the classic conflict situations of former threats. They are not confronted with a heavily armed, militarily organized enemy but with hungry, scared or even enraged civilians. How will they react? Will they remain peaceful or will they become aggressive? Shall the soldiers keep in the background or take strong measures? The answers to these questions are decisive for the operational or tactical proceeding and for the adequate use of material and personnel in crisis regions.

Therefore, instead of concentrating on mutual attrition of relatively symmetric enemies as in the past, rethinking has to take place also in the area of simulation. The highly dynamic character of asymmetric multi-party scenarios must be modeled, non-military groups and the hardly predictable behavior of the civilian population must be appropriately considered and, in addition to weapon employment, active de-escalation and non-lethal methods are becoming increasingly important. Thus, the present and future mission situations of the armed forces are characterized by growing complexity where small changes of the initial situations or of the processes may involve decisive consequences for direct and indirect mission success.

Using agent-based modeling and simulation allows to model these complex dynamics of the real-mission processes (cp. [7]) in which even a misunderstanding between individuals can decide whether a mission is peaceful or not.

The Simulation Model PAX

On behalf of the German Bundeswehr, an advanced agent-based model for the simulation of peace support missions has been developed under the name of PAX (Latin term for "peace") at the System Design Centre of EADS. Analyses with PAX help to better understand the complex dynamics of tactical miniature scenarios, which are so important for peace support missions, and to check alternative procedures. In doing so, a great number of effects can be analyzed in a broad spectrum of realistic mission situations: The simulation of a humanitarian assistance mission, for example, shows not only the apparent success of drastic measures against disturbing elements but also significant side effects, such as arousing agitation, dislike or even hate of a previously friendly group.

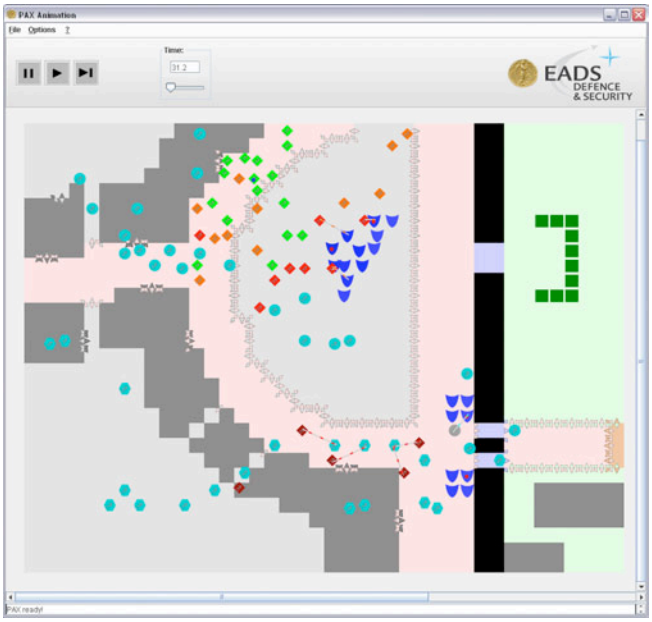

Figure 1: Visualization of a PAX situation in the scenario examined at IDFW14

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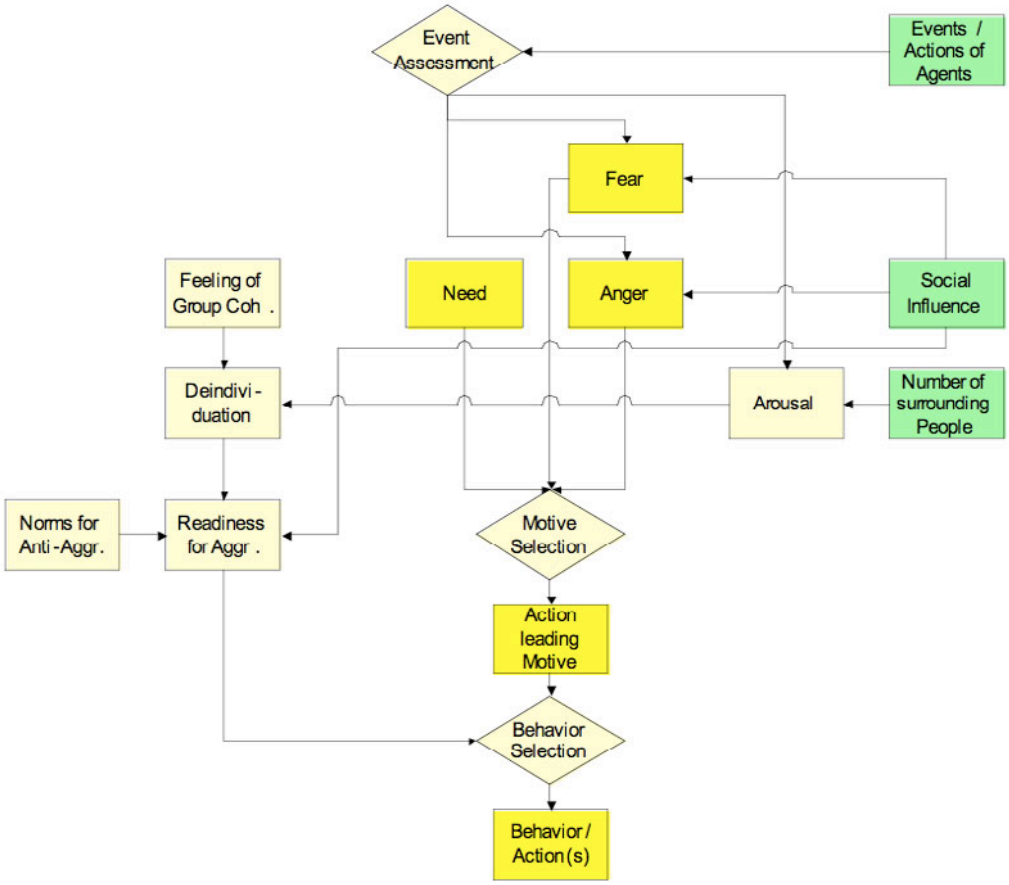


Figure 2: The "model behind the model". Core of a civilian agent in PAX where green blocks represent external variables, yellow ones motives and action

Despite or even because of the technical progress and the automation of many processes, human factors are of great importance in today's mission reality, in particular in peace support missions but also in the scope of Network-Centric Operations (NCO) (cp. [6]). Thus, for example, stress-caused inappropriate behavior in combination with collective aggression may result in the uncontrolled insurgence of crowds. Empirical findings from interdisciplinary areas of psychology, sociology and the military and police sector form the basis for the modeling of human behavior.

Both military expertise and empirical findings from psychological research on aggression were used in the construction of PAX. The psychological model on which the civilians in PAX are based is described in [1], while Figure 2 shows a very simplified diagram of the qualitative correlations in the model. Psychological factors having an influence on the decisions and the behavior of all persons concerned may have a considerable effect on the development of an operation.

PAX concentrates on modeling peace support operations on a detailed tactical level. Since being of secondary interest in the question sets examined, terrain is modeled in a fairly abstract way in a grid-based environment with a distinction between normal cells, built-up cells and obstacles. Due to its nature and objectives, the model focuses on the detailed representation of the individual civilians and their internal states, including emotions such as fear or anger and their interrelation. The military forces modeled in PAX, on the other hand, have the possibility to not only use different types of weapons, as in existing military simulations, but to also take measures of active de-escalation, such as trying to calm down people or talking to the leader of a civilian group.

Toolbox PAX

The current PAX version 3.0 concludes a development aimed at providing the military analyst with means to examine question sets in a variety of easy to set up PSO scenarios. Thus the main goals in the development of this "Toolbox PAX" were to make the model flexible enough to be used in a broad variety of scenarios, examining different aspects of PSO missions, while at the same time keeping the user interface easy and intuitive enough for the military expert to use it without an excessive introduction.

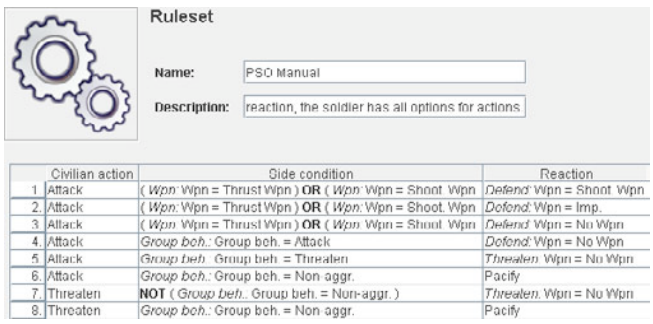
The improvements in the functionality of PAX are best explained by looking at two of the new tools that have been created – namely the Ruleset Editor and the Motive Editor, which are briefly introduced in the following sections.

PAX Ruleset Editor

Different behavior of the soldiers is represented by different rule sets in PAX. These rule sets represent soldiers' rules of engagement, training and TTPs up to a certain extent. While in previous versions of PAX the user was able to choose between different predefined rule sets, the Ruleset Editor now enables the user to define his / her own set of rules.

In doing so, the user may choose from a range of conditions including actions performed by civilians, gender and age of that civilian, the overall behavior of certain groups, the level of escalation, weapons or the force and condition of the own squad.

Using these conditions, the military user can distinguish different cases and situations and thus define the desired reaction of a soldier under any given circumstances.



Ruleset

Name: PSO Manual

Description: reaction, the soldier has all options for actions

	Civilian action	Side condition	Reaction
1.	Attack	(*Wpn*: Wpn = Thrust Wpn) **OR** (*Wpn*: Wpn = Shoot. Wpn	*Defend*: Wpn = Shoot. Wpn
2.	Attack	(*Wpn*: Wpn = Thrust Wpn) **OR** (*Wpn*: Wpn = Shoot. Wpn	*Defend*: Wpn = Imp.
3.	Attack	(*Wpn*: Wpn = Thrust Wpn) **OR** (*Wpn*: Wpn = Shoot. Wpn	*Defend*: Wpn = No Wpn
4.	Attack	*Group beh.*: Group beh. = Attack	*Defend*: Wpn = No Wpn
5.	Attack	*Group beh.*: Group beh. = Threaten	*Threaten*: Wpn = No Wpn
6.	Attack	*Group beh.*: Group beh. = Non-aggr.	Pacify
7.	Threaten	**NOT** (*Group beh.*: Group beh. = Non-aggr.)	*Threaten*: Wpn = No Wpn
8.	Threaten	*Group beh.*: Group beh. = Non-aggr.	Pacify

Figure 3: One of the default rule sets

Figure 3 shows the "PSO Manual" rule set, one of the rule sets built into previous versions of PAX which is still shipped with PAX as a predefined rule set. The "PSO Manual" rule set represents a moderate reaction to civilian actions trying to create a balance between an immediate sharp reaction and a complete laisser-faire attitude. Using the Ruleset Editor this rule set can be easily adjusted or even changed completely.

PAX Motive Editor

While the Ruleset Editor provides the analyst with new means of modeling tactics, techniques and procedures of the soldiers, the behavior of the civilian agents in PAX is a lot more complex. Just like in a real mission, the civilian agents in PAX make their own decisions and follow their own goals, not seldom leading to an unexpected behavior of individuals and – as a consequence – of the crowd. Although this again matches the real-life experience of PSO forces, the analyst often needs a way to not only define the initial state of the civilians in the simulation and then watch the dynamics evolve, but to also make the civilians have certain user-defined objectives or motives.

The Motive Editor accounts for this desire to model predefined goals of a civilian. It allows the user to define *cognitive* motives a civilian is to follow in addition to the existing motives like anger or fear built into PAX. Examples for such a cognitive motive are *need* or *voting motivation*, both used to be defined as "regular" (already pre-defined) motives in PAX. In the new version of PAX these motives are defined as cognitive motives, giving users the ability to flexibly modify them to fit their needs. Thus, a cognitive motive can be seen as a "plan" the civilian wants to follow and allows the user to program scripted behavior for the civilians up to a certain extent.

In the medium-term, the ability to change TTPs not only for the soldiers but also for the civilians paves the way for some sort of war-gaming applications with PAX where BLUE TTPs can be improved to match RED TTPs and vice versa. The new flexibility provided by these cognitive motives was already used by team 1 at IDFW14 by setting up a cognitive motive for one group so they would explicitly assault another group. Figure 4 shows the Motive Editor with the mentioned cognitive motive "Assault" loaded.

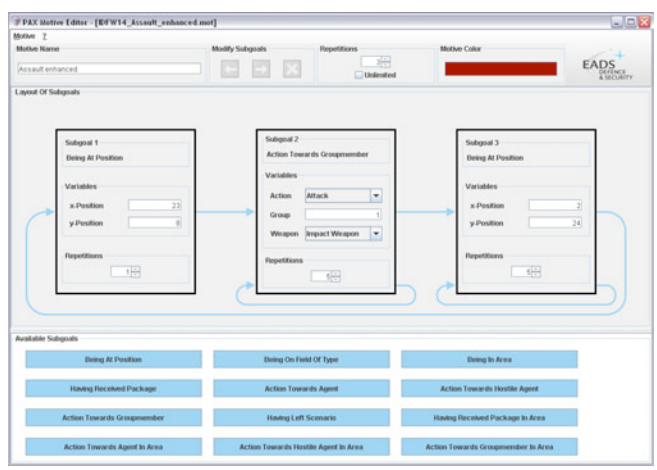


Figure 4: PAX Motive Editor

Each civilian assigned this motive will try to sequentially achieve the sub-goals for three times (see global number of repetitions) as long as no other motive (such as a high anger or high fear) has a higher motivational strength.

Of course, other motives still can *get* a higher motivational strength while a civilian is processing a cognitive motive just due to the dynamic processes in the model.

Example: A civilian has a quite high motivation (strength of the cognitive motive) to cross a checkpoint to go to work. If heavy shooting is taking place on his way around him, the civilian may – depending on his cognitive assessment of the situation and the resulting effect on his emotional state – become fearful and try to run away. In this case, the motivational strength of fear exceeds that of the motivation to cross the checkpoint.

Other Features of the Toolbox PAX

Apart from the editors just described and the according changes to the simulation model, further enhancements have been made to the model as well as to the graphical user interface to allow for a better, easier and more realistic analysis of the question sets at hand.

Improvements to the model include enhanced movement algorithms for the agents, the ability of soldiers to arrest and disarm civilians in a given situation or the possibility of agents entering the scenario at a certain point in time and leaving it under certain conditions.

Another important feature from the analytical point of view is the ability to set every numerical parameter using not a fixed initial value but rather a mean value and a given distribution. This allows both an easier and more realistic setup of scenarios and accounts for random variations of the scenario situation that soldiers are facing in real missions, too.

Some improvements have been made to the user interface, such as the use of tooltips to explain the various parameters that can be defined in PAX or the visualization of different civilian groups using different shapes.

To conclude the description of the toolbox and its capabilities, it should be mentioned that all of the important components of a scenario, such as agents, motives, rules or rule sets, can be saved and thus reused in various other scenarios.

Data Farming with PAX

Analysis with PAX using the method of data farming has been done since PAIW8, both during following Project Albert International Workshops / International Data Farming Workshops (cp. [2]) and in other work done by EADS and by students of the Naval Postgraduate School in Monterey, CA (cp. [3]).

Since then, PAX' support for data farming has been continuously improved so that PAX now assists the user in the whole process of scenario and study creation, execution of the study on either a local computer or a super-computing cluster and analysis of the results. PAX provides an experiment editor for creating OldMcData studies (see [4]) as well as an easy-to-use, Excel-based visualization tool for analyzing data farming studies.

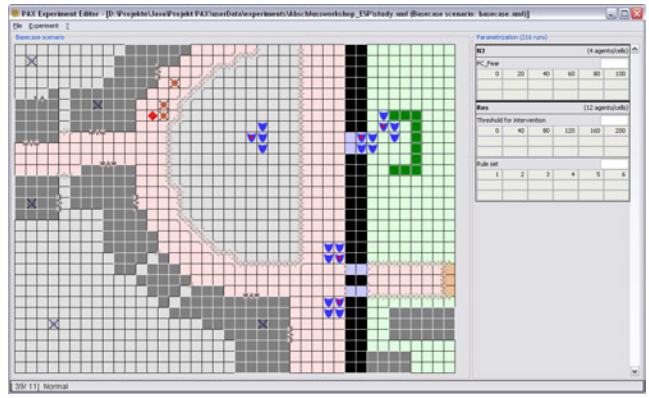


Figure 5: PAX Experiment Editor

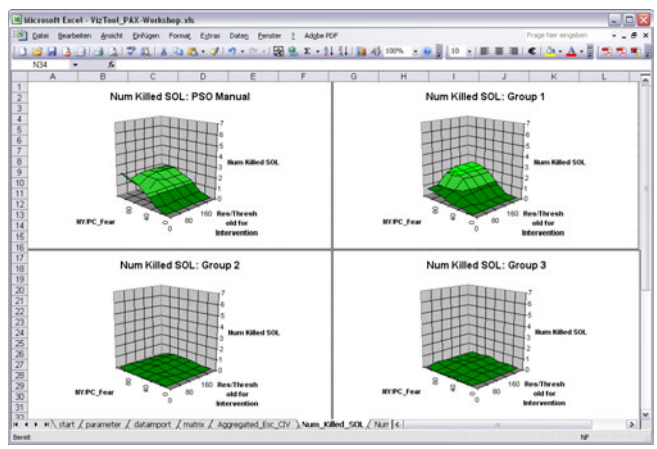


Figure 6: PAX VizTool

Although PAX supports any data farming procedure the user wishes to follow, at International Data Farming Workshops the groups working with PAX usually roughly followed a certain "cookbook":

1. Select a high-level scenario (such as "food distribution" or "demonstration").
2. Build a base case scenario matching the high-level scenario developed in step 1.
3. Find the most significant model parameters using an efficient design (e.g. NOLH) and fitting a regression model to the results.

4. Decide which parameters to data farm (using the parameters found in step 3 and any additional parameters of special interest).
5. Define a gridded study and send the runs to a computing cluster.
6. Analyze the results using statistical tools and methods like regression models and fitness landscapes.
7. Optionally examine single simulation runs in more detail using the PAX animation.

Areas of Application

The main focus of the current version of PAX is the process of analysis and planning. The agent-based modeling approach, combined with the experimentation method of data farming and the usage of high performance computing add up to a powerful instrument for doing a holistic analysis of a variety of question sets with regard to peace support operations. Being able to compare different TTPs on both the military and the civilian side while taking into account human factors on both of these sides creates a new quality of analysis. In addition to the use of PAX for analyzing tactical miniature scenarios, the existing interfaces and modules also enable the use of the model as a zoom function for operational or strategic analyses in the scope of the "Concept Development & Experimentation" (CD&E) process.

Up to now, no activities have been conducted with PAX in the direct context of requirements determination and fulfillment. However, PAX could be applied to analyze the cost-benefit ratio, in particular, of military material used on tactical level. This would require the development of additional modules allowing a more detailed simulation of the technical aspects of the systems used than this has been possible so far with PAX.

As a basis for the future use of PAX in the scope of computer-assisted training, a user interface has already been created which enables the user – in this case the platoon commander to be trained – to directly move in a virtual 3D environment and to interact with the civilians and soldiers simulated by PAX. In order to impart practical skills and behavior patterns in a realistic environment, using this so far prototypical synthetic environment, it would be possible in the future to complement the practical training by additional virtual experience gained with simulation. Special cases as well as "best case" and "worst case" scenarios can be considered and different assumptions on the intentions and behavior patterns of the cultural, ethnic or political groups encountered in operations can be taken into account. In after-action reviews, the trainee can see the consequences of his decisions under didactical aspects as well as potential action alternatives. Especially in the important PSO context, these after-action reviews offer the opportunity of seamless integration of simulation systems into training.

Summary and Outlook

The "Toolbox" version 3.0 of PAX proves to be a useful instrument for the military analyst, even though further calibration is necessary. This conclusion was drawn during International Data Farming Workshop 14 in March 2007 as well as at a national PAX workshop held in April 2007 in Germany with participants from a military and psychological background.

PAX already proves to be applicable for performing useful analyses. But, to further improve the model quality and applicability it is recommended to add further enhancements to the model such as better possibilities for defining tactical courses of action, and to conduct a comprehensive model calibration and further validation.

Follow-up activities are considered in all mentioned areas of application, such as using PAX for training purposes, or to develop and review operation doctrines. Analysis with PAX may become even more powerful in combination with the use of evolutionary algorithms. First ideas for such an approach have been presented in [5].

References

[1] Schwarz, G. and Mosler, H.-J. Investigating Escalation Processes in Peace Support Operations: An Agent-based Model about Collective Aggression In Proceedings of the 3rd Annual Conference of the European Social Simulation Association (ESSA 2005), ESSA, Koblenz, Germany, 2005.

[2] Schwarz, G. and Erlenbruch, T. Experiments with the Model PAX: Investigating Escalation Processes in Peace Support Operations. In Maneuver Warfare Science 2003. USMC Project Albert, Quantico, VA, USA, 2003, 63-79.

[3] Soon Tan, P., Using Agent-based Modeling to Assess the Impact of Martial Law on a Representative Iraqi Town, Master Thesis in Operations Research, Naval Postgraduate School, Monterey, CA, USA, 2004.

[4] Koehler, M. T., Upton, S. and Tivnan, B. F. Clustered Computing With NetLogo And RepastJ: Beyond Chewing Gum and Duct Tape. In Proceedings of the Agent 2005

Conference on Generative Social Processes, Models, and Mechanisms, University of Chicago, IL, USA, 2005.

[5] Lampe, T. and Schwarz, G., Using Evolutionary Algorithms to Improve Tactics, Techniques and Procedures in Peace Support Operations, At the Military and Security Applications of Evolutionary Computation Workshop (MSAEC 2006), MSAEC, Seattle, WA, USA, 2004.

[6] Schwarz, G, Command and Control in Peace Support Operations: Model PAX – Approaching new Challenges in the Modeling of C2 /– In: The 9th ICCRTS at the House of Engineers in Copenhagen, Denmark (14-16 September 2004) ; (http://www.dodccrp.org/events/2004/ICCRTS_Denmark/CD/papers/062.pdf).

[7] Schwarz G.; Kunde D.; Urban C., Agent-Based Modeling in Military Operations Research: A Case Study – In: 3rd Workshop on Agent-Based Simulation / C. Urban (ed.), SCS – Society for Computer Simulation Int. ; Delft ; Erlangen ; Ghent ; San Diego, 2002, p. 55-60.

International Data Farming Workshop 15

When: 11 - 16 Nov 07
Where: Novotel Clarke Quay, Singapore, 177 A River Valley Road. Singapore 179031
Hotel information available at (http://www.novotel.com/novotel/fichehotel/gb/nov/5993/fiche_hotel.shtml)
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Details on room rates and how to make reservation will be announced soon. Please watch http://harvest.nps.edu/ for additional information.

The workshop fee will be S$800 (about 525USD) to be collected on site.

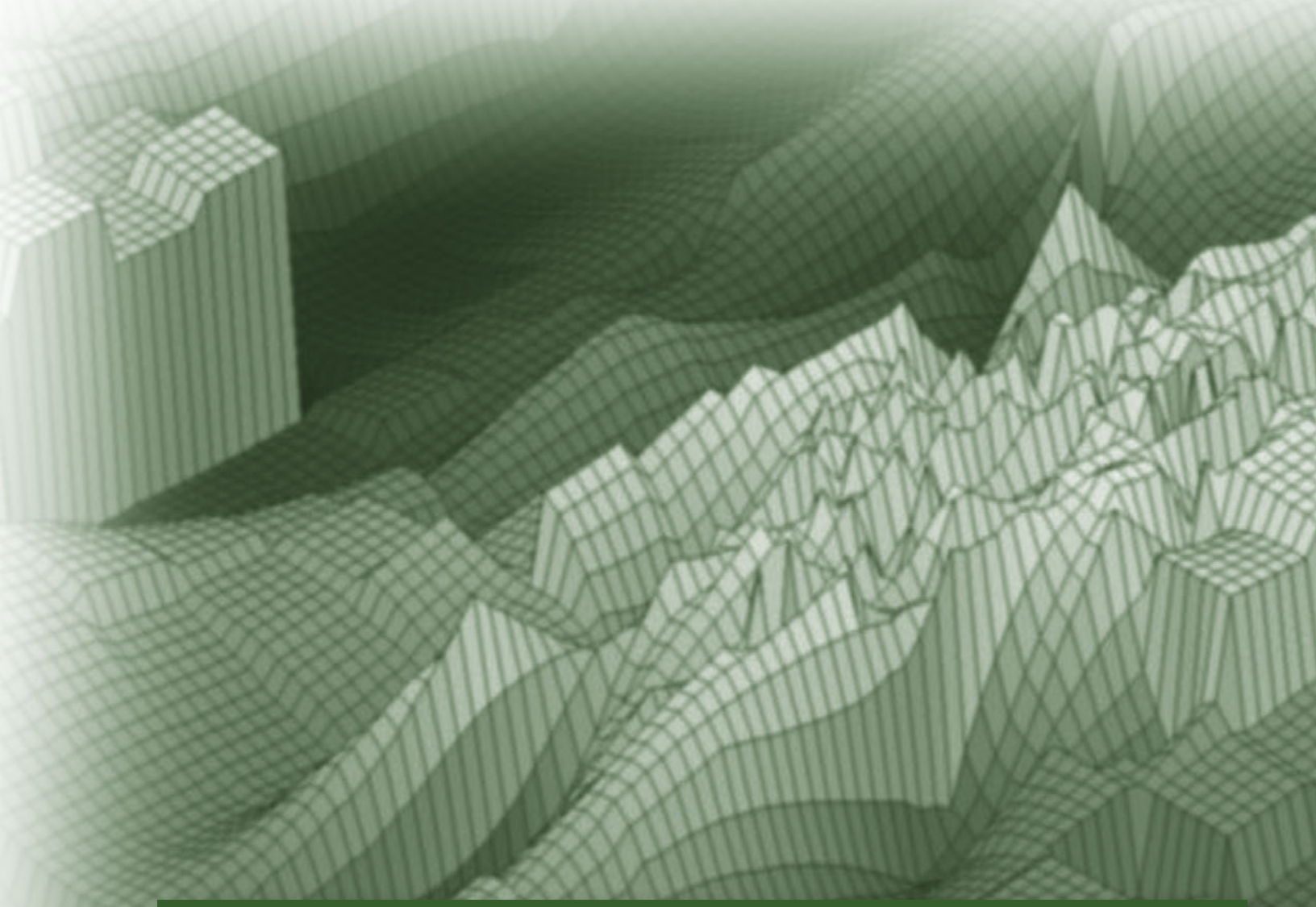
Tentative Agenda
Sunday, November 11: Opening dinner, gather at 6 o'clock
Monday, November 12: Opening briefings, 0800
Tuesday - Thursday, November 13 - 15: Work in teams, Concurrent morning plenary sessions
Friday, November 16: Team Brief-outs and Closing Ceremony Start at 0800, finish by noon

Call for Team Leaders / Plenary Speakers:
Please email gehorne@nps.edu with your choice of teams and if you want to lead a team or present a plenary briefing.

Conference Fee:
The registration fee is expected to be S$800 (currently ~$525 US). Payment detail will follow. Registration pays for:

- Conference rooms
- Included food and drinks
- New one-year membership card with quote
- Opening dinner
- CD with conference materials
- Fun

The Data Farming CD/DVD, if provided, will be attached here. For addtional copies of the CD or of the Scythe please contact Ted Meyer (tedmeyer@mac.com)



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